THE

CLEANING AND SEWERAGE OF CITIES.

BY

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INTRODUCTORY.

THE literature on sewerage and allied subjects is quite extensive. Even in America numerous publications have appeared, covering more or less thoroughly certain special systems or questions which have arisen from time to time. Much of our literature is in the form of reports or is contained in periodicals and in the proceedings of societies; but no general and comprehensive treatise on sewerage has yet appeared in this country. The publishers of the present volume have therefore done a good service in preparing for American readers a translation of Prof. BAUMEISTER's recent work.

The author, whose name is already familiar to a number of American engineers, is well versed in the subject, though not a practising engineer. His object has been to present in a compact form the elementary principles which govern all the essential parts of a design, and to confine himself to the usual practical questions, rather than to dilate on the more intricate problems which occasionally arise. His impartiality, characteristic thoroughness, and judicial temper have fitted him to present the subject-matter, concerning which all controversy has not yet ceased, in a more balanced and scientific form than I have seen in any other book. We can therefore credit this work with the additional merit of tending to restrain any reader from plunging headlong into theories and practices which, both in Europe and America, are occasionally advocated by parties who fail to see all sides of the subject, or who are biased in the direction of their personal interests.

In using this book for practical purposes, the American reader should realize that it was written primarily for German engineers, and for conditions prevalent in the German Empire. Although the collection, treatment, and disposal of sewage must accomplish the same object in every civilized community, we must remember

the fact that social customs, domestic appliances, climate, and rainfall are in some respects different from what they are in our own country, which will modify some features of the works. The data and recommendations which are suitable for Germany should therefore not necessarily be accepted and applied here without intelligent examination and scrutiny. I shall endeavor to point out below some cases where American conditions require a different practice.

The first part of Prof. BAUMEISTER's book—here omitted—concerns plans for the extension of cities, for pavements, and street railways. This omission is justified by the existence of publications on these subjects which are well adapted to American wants. The second part—forming the present volume—concerns the design and construction of sewerage works, the purification of sewage, street cleaning, and refuse removal.

After stating the general principles governing grades, depth, outlets, and alignments, the author, in Chapters 2 and 3, enters upon the question of the quantities of sewage and rain-water to be provided for. It is asserted that the German practice in designing water-works is to allow 40 galls. per head per day. In America the water consumption is much greater and also varies in different cities, reaching in some instances more than three times the above amount.

The character of the sewage, its chemical composition and dilution will vary correspondingly. Likewise, the data concerning rainfalls and the amount reaching sewers are not entirely suitable for American conditions. We have heavier downpours and they are more frequent than in Europe. The author, moreover, credits us very truly with being "less willing to put up with the inconvenience of overflowed streets and cellars."

When we apply the deductions of Prof. BAUMEISTER to works in America, we must therefore modify his figures and conclusions accordingly.

The methods, however, according to which these data are to be weighed and applied are well presented, and their description thus furnishes information which is of course equally applicable to our own conditions.

The chapter on the shape of sewers describes more completely than I believe is found in any single publication the characteristic forms for various conditions occurring in practice. The

chapter pertaining to the methods for the calculation of sizes embodies the latest and best formulas and convenient diagrams to facilitate the necessary computations.

The details of construction, such as manholes, lampholes, junctions, overflows, siphons, and outlets, are quite fully treated and well illustrated, with a view to showing the proper variation in the designs for different conditions. These details are applicable and many will be equally serviceable in American practice. The remarks on relief outlets or stormwater overflows are particularly useful.

The chapter on catch-basins and street-water inlets describes some devices which are not suitable for general use in this country. The great care given to the cleaning of sewers in Europe frequently permits the use of the more simple and direct inlets without either catch-basin or trap. In America such would, as a rule, be objectionable, though occasionally their use might be satisfactory.

Flushing and ventilation are subjects which as yet have received insufficient attention in America, particularly in those of our cities having combined systems of sewerage; the many suggestions of Prof. BAUMEISTER will therefore be of special value. Regarding the automatic flushing appliances, the American reader will observe several curious statements, some slight confusion of names, and the omission of some of our best appliances.

The advantages and applicability of the separate system of sewerage are stated in a manner which plainly indicates the author's broad and impartial views.

The chapter on cost is, again, one which cannot be applied to American conditions without caution and without a knowledge of the difference in prices and methods of working. It will be noticed that in many instances the cost is not far from our own, sometimes exceeding what we think is an average price in this country. Any one who observes the practical operations of building in both countries will, I think, find the explanation in the circumstance that, while the average American mechanic and laborer are paid higher wages, their work is generally done with greater energy, and they are assisted by a greater number of labor-saving appliances.

The second part of the work before us pertains to the purification of sewage. At the present day there is published prob-

ably nowhere else, within the same short space here devoted to it. a more complete and rational account of this subject. The conclusions, as far as they are given, may generally be followed under ordinary conditions prevailing in this country. The questions of pollution and self-purification of rivers receive due consideration.

The chapters on chemical precipitation contain a good deal of matter with which American readers have not as yet been made familiar, particularly in regard to the smaller plants as used in Germany. The annual cost of precipitation ranges from 11 to 24 cts. per capita, but it is not safe to estimate on these figures in this country.

The purification of sewage by aëration, filtration, and irrigation are each given a careful consideration. The information pertains more to results and cost than to methods and details of design; but there are a number of suggestions regarding the latter which will be found valuable.

The volume closes with a part devoted to the questions of general municipal sanitation, street cleaning, garbage and excrement removal, and disinfection. While we might consider some of the contrivances mentioned as unsuitable here, the general recommendations are sound, and if faithfully followed would much improve the condition of our cities.

RUDOLPH HERING.

March, 1891.

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PART I.—SEWERAGE.

CHAPTER I.

General Principles.

On account of the great diversity in local surroundings, it is impossible to give fixed rules to be followed in designing sewers, but only a statement of the general principles underlying all such work. These principles and the details of construction are essentially independent of the character of the sewage and the system of sewerage designed to remove it. We may take as a type the complete water-carriage or combined plan.

1. *Grade of Sewers.*—It is usual to assume, as a result of English investigation, that a velocity of the water of from 2 to 2.6 ft. per second is sufficient to carry off all solid matter which may enter the sewers. In smaller lines, where the current is often checked, from 3.3 to 3.9 ft. per second may be necessary. Since the velocity varies with the depth of water, the question arises as to what quantity of water is to be specified in determining the minimum velocity—a question which is rarely clearly stated or answered. Of course the maximum amount of water (rain and carrying) must be able to pass at that rate, also the maximum flow of carrying water per hour in dry weather and, if possible, the average hourly flow, should have this velocity in order that the solids may be kept in suspension. By carrying water is meant that part of the water supply which reaches the sewerage system after employment for various domestic purposes. It is easier, as a rule, to prevent a deposit in sewers by maintaining a reasonable velocity than to flush out such matter after it has settled. Practical experiments show that sewers of the usual sections will remain clean with the following minimum grades:

Separate house connections, 2 per cent.; extreme cases, 1 per cent. See note, page 279.

Small street sewers, 1 per cent.; extreme cases, 0.7 per cent.

Main sewers, 0.7 per cent.; extreme cases, 0.5 per cent.

The extreme cases are for sewers carrying only rain or quite pure water.

The following empirical formula will give the minimum grade for a sewer of a clear diameter equal to d inches, and either circular or oval in section.

$$\text{Minimum grade, in per cent.} = \frac{100}{5\,d + 50}.$$

In Wiesbaden, the least grade was calculated on the assumption that with 0.8 ins. depth of water, the velocity would be 1.83 ft. per second. Knauff advocates a velocity of 2.3 ft. per second in house connections running with a depth of water equal to one-fourth their diameter. This would correspond to a velocity of 3.28 ft. when the pipes are full.

Where it is impossible from local or financial causes to maintain clean sewers by giving them a proper grade, flushing or mechanical cleaning becomes necessary. But flushing tanks are desirable and usual in systems with grades above the minimum, since their use renders the removal of deposits fairly certain. Experience shows that sewers cleaned in this way always have better air than others, even when the latter are self-cleansing. As the lowest limit of grades which can be flushed, 0.1 to 0.2 per cent. may be assumed for sewers which are sometimes dry, while 0.03 per cent. is allowable for the trunk sewers in cities like London, Hamburg, Mannheim, Dusseldorf, and Brussels. Exceptions to these rules can always be made in places on the sea-coast or tidal rivers, such as Westham and Hamburg, where the flow is maintained by gates opened and closed at the proper stages of the tide or by other means.

Although the slope should preferably be steep, in order to economize in material and cost, yet there are maximum limits beyond which the velocities generated would cause the water to wear away the sewers or would carry off the water so quickly that the solid matter would partly remain. The water should not flow away too fast, as the early formation of a tolerably constant current in the entire system would thus be prevented. The sewers should be dry as rarely as possible. On this account it is not usual to exceed a velocity of 5.9 ft. in England: the street sewers

of Berlin have a maximum grade of 2.0 per cent., in Lubeck of 4 per cent. In steep streets in Stuttgart and Mainz grades of 8 per cent. still occur, and in necessary cases almost perpendicular descents of a few feet are made. The maximum grade of house connections is fixed at 5 per cent. in many places, but it would seem better to specify a uniform grade in the pipes and thus avoid the use of knees, as these drains run dry under all circumstances.

Since any checking of the current causes a deposit of the suspended solids, it is desirable to maintain the same velocity throughout the entire sewerage system, especially with low water in the pipes. Hence the grades in sewers of the same class should be everywhere equal. For the same purpose, lines which carry but little water should receive more of a slope than the others of similar sections. The grades of the entire net-work should be determined in this way, provided the points mentioned in the next section do not modify the plan.

2. *Sewer Depth below Street Surface.*—Economical construction calls for sewers as near the surface of the streets as possible. The least depth is determined by the position of the house connections and by the frost line, which is never less than 4 ft. below the surface. Moreover, it is desirable to have the sewers so low that the bottom of the cellars can be drained and the water in the soil carried off. For this purpose, from 10 to 13 ft. can be assumed as a minimum depth, while 7 to 10 are sufficient when cellar drainage is neglected. The usual depth of sewers in Frankfurt varies from 13 to 20 ft.; the average is 17 ft. In city extensions, it is often necessary to decide between raising a street level or lowering a sewer, and a further complication occurs when it is necessary to form connections with a flushing reservoir at a fixed elevation.

When the street grade is often changed, a fixed position of the sewer, relatively to the road bed, cannot be maintained; sometimes a depth of over 30 ft. occurs and tunneling is necessary in construction. In very steep streets, the sewers are laid like a flight of steps, with a shaft at every step, down which the sewage falls. The large trunk sewers are constructed with little reference to the lay of the land, since they receive tributary lines at but few points. At Paris and Hamburg large tunnels have been driven for these sewers, but it is sometimes possible to avoid the cost of such works by using siphons on a large scale.

3. *Outlets.*—The ocean, lakes, rivers, canals and moats have all been used as receivers of sewage. It is often very important to determine if the sewers can lawfully discharge their contents in the intended manner; it sometimes happens that only storm sewers or the drains from good chemical, irrigation or filtration plants are allowed to empty into rivers or canals. Small brooks, industrial canals and similar streams often receive sewage and become drains of the worst character. In order to clean and adapt them for carrying such matter, they should be turned into trunk sewers, provided their position allows of this and their occasional open stretches are few and short, as in Karlsruhe, Vienna, Worms and Essen. When this is not possible, it is the duty of the authorities to block up all the places at which the offensive matter enters and parallel the canal or brook with a trunk sewer to receive the sewage, as has been extensively done in Brussels, Stuttgart, Wiesbaden, Basle and Vienna. The same measures apply to ditches and navigable basins that are used in many towns as dumping-places for all kinds of refuse. Sometimes a canal can be closed at both ends of the part used for traffic and the sewage carried under or around it by a special sewer, as is done in Hamburg. Where, however, canals must be used for traffic and as receptacles for sewage, adequate means for diluting the latter must be provided. In Amsterdam there are facilities for adding to the canals each day an amount equal to their own volume of water, and at the Hague an amount equal to half the contents can be supplied.

In general, the outlets of a sewerage system should be placed so high that the effluent can escape at all stages of the water into which it flows. This does not exclude a quick fall in the outlet sewers, for the purpose of keeping the mouths of the drains generally or always under water and out of sight. The last sections thus remain continually full of water, which does not, however, interfere with their working. The outlet in Munich is arranged as shown in Fig. 1. The main sewer empties above the low water level, but a smaller iron pipe leads down to a point always submerged. In this way, the foul parts of the sewage are always discharged below the surface of the

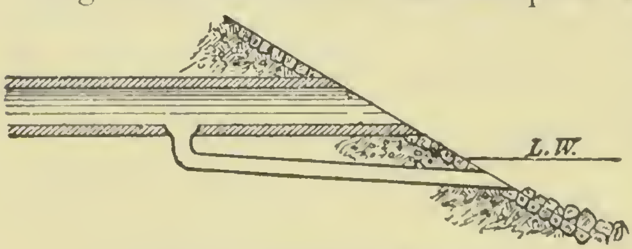

FIG. 1—OUTLET AT MUNICH.

river, while the rain water, which is of large volume, is sometimes seen during low water to flow from the mouth of the trunk sewer. Rivers which carry much sediment and have shifting beds must be carefully examined before locating the outlets, or the latter may become stopped with sand.

Where the sewage is discharged below the high water level and the sewer grades are very flat, the outlets must be closed part of the time. In Dresden-Altstadt there are 15, in Crefeld 16, in Cologne (proposed plan) 20 days in the year when more or less setting back of the sewage occurs in the sewers, as is the case at every flood tide in Hamburg, Bremerhafen, Emden and also many English towns on the coast. In such cases, the water from the receiving basins, rivers or sea either enters the sewers, or the outlets are closed and the sewage retained in the system, which thus becomes a sort of a reservoir and must be designed accordingly. At Hamburg, the sewage is discharged into canals while the outlets are closed, and at Emden large reservoirs, containing 8 days' effluent, have been formed by earth dams. See note, page 279.

Where high water lasts during the greater part of the time, or where the sewage must be raised for irrigating or other purposes, recourse must be had to pumps. When these are not continually in use, they are an expensive investment and it is wise, in making the first designs, to see if the most economical expenditure of the capital at hand would not be attained by a general raising of the streets and sewers. The economical working of the pumps can be sometimes increased by building receiving basins to hold the large quantities of water that occasionally are discharged. In London, masonry reservoirs with flushing appliances are used for this purpose, while in Mannheim large ditches are employed.

4. *Relief Outlets.*—In many cities there are opportunities for building relief outlets, openings in the sewers at a certain height through which the sewage can escape when rain has increased the depth of the contents so that their level is above the bottom of these outlets. The section (wetted perimeter) of the sewers below these outlets need not be so great as would be the case without them, and every outlet diminishes the expense of construction. When the rain water begins to enter the system at a number of points, the carrying water will be diluted and discharged more rapidly. Since the reliefs first act when it has rained for some time and the street refuse has been swept away,

the discharge from these side outlets is fairly pure water, which may be allowed to run off in small pipes. The height of the outlets is determined by the degree of dilution which the sewage shall have before being discharged. The effluent from these openings may be carried off through old sewers or in any suitable manner. It is generally better to distribute a considerable number of them over the whole sewerage system rather than concentrate a few in a limited district, since the action of the sewers is more uniform, and the river, or other receptacle of the overflow, does not receive a large mass of water at a single point. Therefore the old sewers and brooks should be utilized whenever possible, and the construction of new drains to the more remote districts never be omitted when they may be of advantage.

5. *Systems of Sewers.*—Five different methods of dividing a town into collecting districts and laying out the main sewers can be recognized.

(*a*) *Perpendicular System.*—Where a city is divided by a watercourse of some kind, or is bounded on one side by such a body, it is usual to divide the area into a number of districts with entirely distinct systems. Each district has its trunk sewer and branches, and is approximately at right angles to the body into which its sewage flows. Halle, Salzburg, Vienna, Ulm, Rostock, Bern, and Szegedin are arranged in this way. The advantages are due to the short length and small section of the sewers. The disadvantages are a possible overflow in the lower parts of the city due to heavy discharges, in rainy seasons in the upper districts, and the pollution of the river, or other body, within the city limits. These evils are avoided in the

(*b*) *Intercepting System.*—Intercepting sewers are run along the banks of the river and receive the sewage of the several districts, discharging it below the city or on suitable filtration beds. This plan is sometimes adopted after the disadvantages of *a* have been felt, as at Brighton, Dresden, Kassel, and Strassburg. The first system may be so designed that it can be easily changed into this when necessary, and the small deposits that may occur in the river at first can be removed by dredging. An intercepting sewer is usually expensive on account of its large size; moreover, it is so low that relief outlets are sometimes impossible. On the other hand, when pumps are necessary, this system enables them to be concentrated at a single station. In Pest, where the first system

with 6 separate steam pumping stations was formerly used, this plan was adopted, and the pumps all concentrated in a single station, operated by water power.

(*c*) *Fan System.*—In this plan, from a single main outlet a number of radiating trunk sewers lead off in different directions and thus, through their branches, drain the whole city. One of the districts, that comprising the center of the city, is usually much larger than the others. Karlsruhe, Wiesbaden, Emden, Breslau, Dortmund, Bremen, and Brussels offer examples of this plan.

(*d*) *Zone System.*—In this construction, the district to be drained is divided by contour planes; the zones usually have separate receiving sewers and are connected for flushing purposes only. The advantages are due to the diminished difficulties at the outlets (in pumping, closing gates, etc.), the lack of large quantities of water in the lower parts of the city, and the small section that may be given the receiving sewers if a modification of the intercepting system is used. It is also advantageous at times to have a number of filtration beds, and this plan enables them to be easily located at different heights. The fan system is usually employed in the different zones, although the intercepting system often offers some advantages. Frankfurt, Mainz, Dusseldorf, Stuttgart, Heidelberg, Paris, Munich, and London are types.

(*e*) *Radial System.*—In this system, the city is divided into a number of sectors and each of these drained from the center outward. A number of filtration beds with the necessary pumps are often located around the city. The great advantage of the plan lies in the fact that the small sewers are in the center of the city and the sections grow in size as the distance from this center is increased. In this way, the lines already laid are fairly certain to remain the proper size for some time. In the intercepting and fan systems, the trunk sewers are designed for an assumed population which may be exceeded and new and expensive lines made necessary; moreover, the growth of the city is continually adding to the number of small sewers on the outskirts, and the sewage thus added must be provided for by the old lines, which were designed without reference to any possible annexed territory in the future. The greater the city, the more advantageous does this radial plan become. Berlin is an excellent type.

Of course, there are many combinations of these systems that

can be made; the sewer nets of Hamburg, Liverpool and Cologne offer interesting examples of this.

6. *Branches.*—Each street sewer and its house connections forms a miniature system and should be carefully planned. It may be generally assumed that for each drop of water to be carried off there is one shortest path by which it can go. The presence of steep grades, however, often makes the use of winding drains necessary in order that a sudden change of velocity where the drain and sewer join may not cause a deposit of solid matter.

Great care is necessary in designing the flushing system. In flat districts, the flushing water must be furnished through pipes relatively high as compared with the sewers. When a line with a flat grade is joined by others which are steeper, the latter may be utilized as flushing drains for the former by giving proper bends to the connections.

In general, the question of a system of complicated sewers is not solved by laying a number of equally important lines, but by leading the drains to a common center. It is cheaper to build a single system of $n\,x$ capacity than n systems of x capacity. But it is sometimes more economical to lay a main sewer of a size only sufficient for present needs, and afterward lay a parallel line when greater sections are necessary.

Dead ends are to be avoided; two parallel sewers should be connected at their ends, and in such a manner that the contents of one will flush the other. Moreover, the ventilation is much superior if the system is a continuous one. In some cities, Berlin, Dusseldorf, Mannheim, Pest, Innsbruck, Paris, two sewers, one on each side of the street, are used instead of a single one in the center. This plan reduces the length of the house connections and betters their grades. The cost of the system is much greater than with a single sewer, however, and it is more difficult to keep them clean.

CHAPTER II.

Carrying or Waste Water.

From tables prepared by Grahn and Thiem, it is certain that the consumption of water in German cities has an average daily value for the year of from 4 to 58 galls. a person, generally from 6.6 to 37 galls. Household purposes do not call for more than 10.5 to 12 galls. The larger figures that are sometimes found, especially in America, are due to wasteful habits. The presence or absence of water-closets makes no essential difference. Their *future* use should be provided for, however, in the provisions for flushing and cleaning the sewers. In designing water-works, the present German practice is to allow 40 galls. per day per person; in England 28 Imperial, or 34 United States galls. are taken as a basis in designing water-carriage sewer systems. In manufacturing districts, special provisions must be sometimes made for carrying off exceptionally large volumes.*

The radial system used in Berlin offers special advantanges for the determination of the difference in water consumption among different classes of people. The sewage pumped from a thickly populated, but poor district, averaged, according to the 1887–88 report of the Commissioners, 21.1 galls. per day per capita; in districts with a larger street surface and somewhat higher class of residents, 26.4 galls.; in manufacturing districts, 37 galls.; in the most fashionable districts, 44.9 galls. The average consumption of all the districts was a little over 26 galls. The city water-works supply 16.9 galls. daily to each person, and private sources add some 13.2 more, making a total average supply of 30.1. This amount is in excess of the sewage pumped away from the city, and shows conclusively that in designing the sewers for large areas it is not necessary to regard the entire water supply as flowing away through the system. The difference between the supply and effluent is probably due to the quantities used in sprinkling, cleaning and such operations, which result in considerable water soaking into the ground.

The sewers must be able to dispose of the maximum quantities furnished by a fluctuating source of supply. On the days of greatest consumption, the averages given above will be $1\frac{1}{2}$ times

* Page 280.

as large. Moreover, the hour-maximum in the day varies from $1\frac{1}{3}$ to $1\frac{2}{3}$, average $1\frac{1}{2}$, times the hourly mean. Hence the capacity of a sewer must be designed to remove hourly

$$\frac{1\frac{1}{2} \times 1\frac{1}{2}}{24} = \frac{1}{11}$$

of the average daily quantity or about twice the amount calculated on the supposition that the same quantity of sewage was supplied each hour of the year. In the *Handbuch des Wasserbaues* by FRANZIUS and SONNE, the daily maximum is fixed at $1\frac{1}{4}$, and the hourly at $1\frac{2}{3}$, making the relation between the latter and the daily average

$$\frac{1\frac{1}{4} \times 1\frac{2}{3}}{24} = \frac{1}{12} \text{ approx.}$$

American engineers assume the daily maximum as $1\frac{1}{2}$, and the hourly as $1\frac{1}{3}$, making the relation between the latter and the daily average.

$$\frac{1\frac{1}{2} \times 1\frac{1}{3}}{24} = \frac{1}{12}$$

Another method of investigation is based directly on the average daily sewage, since it does not necessarily follow that the maximum daily effluent will be coincident with heavy rains. On this supposition it is usually assumed that half the discharge takes places in from 4 to 9 hours of the morning. This gives a maximum hourly flow of from $\frac{1}{8}$ to $\frac{1}{18}$ of the average daily amount, and the mean is again about $\frac{1}{12}$.

In order to apply these results to the system of any place it is necessary to know the density of the population. In German cities this varies from 49 to 202 persons per acre, but in single districts it is sometimes still greater. In American sewerage design it is customary to calculate on from 30 to 60 per acre, but in some places these figures are exceeded. The future population must be estimated by a careful study of local surroundings, and is usually taken at from 10 to 50 per cent. larger than the present. Or the greatest density in any one district can be assumed as the future density in all. In this way the maximum number of people per acre in great cities may probably be fixed at 325. In designing trunk sewers, provision must also be made for the annexation of new districts to the present city limits, provided that the cost of such an enlarged sewer is not greater than that of a subsequent parallel one.

From such data the proper capacity of a sewer can be calculated for disposing of the necessary number of cubic feet per acre per second, the usual compound unit used in such computations. As an aid in beginning such a calculation, the following table of the estimates used in designing a number of systems, some not yet completed, is given.

Where it was possible to obtain the numbers for the sewerage estimates of the separate districts, these have been given. The numbers for entire cities give the average density of population over the entire area and are used for the outlet trunk sewer designs. The density of single wards and the capacity of single sewers may be far different. Where no figures have been given for future densities, it is assumed that the increase in population will be in districts at present thinly populated.

TABLE I.—ESTIMATES OF THE AMOUNT OF CARRYING WATER.

City.	Mode of estimating.	Gallons a day per capita.	Hour max.	Inhabitants per acre. Present.	Inhabitants per acre. Future.	Cu. ft. an acre a second.
Berlin	Average population	33.5	$^1/_{18}$	81— 202	324	0.022
Berlin	Suburbs	33.5	$^1/_{18}$	.....	162	0.011
Berlin	Average of five sectors.	33.5	$^1/_{18}$	137	270	0.019
Breslau	Separate districts	32.8	$^1/_{16}$	.....	101	0.008
Chemnitz	Separate districts	26.4	$^1/_{18}$	101— 202	.....	0.006— 0.012
Danzig	Right bank of Vistula.	23.8	$^1/_{16}$	194	214	0.012
Danzig	Left bank of Vistula.	23.8	$^1/_{16}$	73	146	0.008
Dortmund	Inner town	33	$^1/_{16}$	135	.....	0.011
Dortmund	Entire city	33	$^1/_{16}$	28	38	0.003
Dusseldorf	Old city	33.5	$^1/_{18}$	243	405	0.028
Dusseldorf	Other parts	33.5	$^1/_{18}$	61— 101	162	0.012
Emden	Separate districts	21.1	$^1/_{12}$	81	.....	0.006
Frankfurt	Entire city	39.6	$^1/_{12}$	.....	81	0.010
Hamburg	Suburbs	37	$^1/_{18}$	.....	101	0.008
Cologne	Old city	37	$^1/_{12}$	162	.....	0.019
Cologne	New city	37	$^1/_{12}$	101	.....	0.012
Kœnigsberg	Entire city	39.6	$^1/_{16}$	222	307	0.029
Karlsruhe	Separate districts	39.6	$^1/_8$	32— 162	162	0.031
London	Separate districts	37	$^1/_{12}$	40— 174	.....	0.005— 0.020
Mannheim	Inner city	42.3	$^1/_{18}$	121	162	0.015
Mannheim	Neckar suburb	26.4	$^1/_{18}$	.....	109	0.005
Munich	Separate districts	39.6	$^1/_{16}$	22 190	32 283	0.004— 0.039
Nuremburg	Separate districts	23.8	$^1/_{16}$	.....	219	0.012
Pest	Separate districts	41.7	$^1/_{20}$	.....	202	0.016
Wiesbaden	Thickly peopled districts	26.4	$^1/_{18}$	.....	162	0.009
Wiesbaden	Thinly peopled districts.	26.4	$^1/_{18}$	.....	101	0.006
Wiesbaden	Suburban districts	26.4	$^1/_{18}$	.....	30	0.002
Vienna	Separate districts	....	....	.....	.....	0.010
Witten	Separate districts	31.7	$^1/_{12}$	67	121	0.012

CHAPTER III.

RAIN WATER.

In designing water-works, it is necessary to know the maximum precipitation for one day, one month and one year, and especially the average fall during continued storms. These data, however, are only useful in sewerage design in determining the dimensions of the outlet basins, when such are used. At Emden, for example, the basins are calculated to hold $\frac{1}{4}$ of the maximum monthly rainfall plus $\frac{1}{4}$ of the amount of waste water flowing in a month. Moreover, the design of sewers depends somewhat for its data upon the short heavy storms over a small area which result in large quantities of water quickly finding their way into the catch basins. It is not sufficient to know the rainfall per hour; the severity of a storm often reaches a maximum during from 10 to 20 minutes only, and this maximum should be determined if possible. The following record, made during a long storm at Zurich, on June 3, 1878, illustrates this point:

Average	precipitation,	11 hrs..........	0.37	cu. ft.	per sec.	per acre.
Maximum	"	30 min..........	2.04	"	"	"
"	"	10 "	3.03	"	"	"

Exact observations of these phenomena require self-registering instruments, and are therefore very scarce. The subjoined table gives a number of measurements in different cities and shows the great precipitation that must be provided for. The compound unit adopted, cubic feet per second per acre, is better adapted to engineering purposes than the usual meteorological one of cubic inches per hour per square inch.

The lack of careful measurements in the past renders it a matter of some doubt as to how high the maximum rainfall must be assumed. Wherever the maximum of a city is considerably below that of places similarly situated as regards meteorological conditions, it is safe to assume that the maximum registered in the past will be exceeded in the future, especially if the region is liable to cloud-bursts. The influence of neighboring mountains is evident from the table. HELLMANN recommends from 2.43 to 2.86 cu. ft. per second per acre for the level plains of

North Germany, while in the Alpine regions, numerous cases of over 4.28 cu. ft. have been observed.

TABLE II.—MAXIMUM INTENSITY OF RAINFALL.

PLACE.	Time.	Duration, minutes.	Cu. ft., per sec. per acre.	Authority.
Albany	July 10, 1876	10	7.32	Weather Rev.
Annaberg	Sept. 10, 1867	15	3.81	Hellmann.
Berlin*	Oct. 6, 1883	15	2.63	Meteorological
Berlin*	May 15, 1889	20	2.69	Society.
Bern	June 19, 1877	45	3.49	Bürkli.
Boston	July 20, 1880	12	4 30	Eng. News.
Budapest*	June 26, 1875	60	2.61	Bürkli.
Chemnitz	June 3, 1886	15	4.37	Deutsch. Bauz.
Czernowitz	Aug. 21, 1869	20	3.37	
Dresden	June 17, 1885	12	4.17	Deutsch. Bauz.
Galveston	June 4, 1871	14	16.91†	Weather Rev.
Gütersloh	July 29, 1838	7	4.87	Hellmann.
Karlsruhe*	June 29, 1885	60	3.89	
Kassel	May 21, 1872	30	2 70	
Kiel	Oct. 3, 1879	20	2.81	Hellmann.
Klausthal	July 21, 1864	25	3.43	Hellmann.
Kœnigsberg	June 16, 1864	45	2.90	Wiebe.
London*	Aug. 1, 1846	60	3.96	Bürkli.
Lugano	Sept. 8, 1873	36	5.14	Bürkli,
Mannheim	July 21, 1888	20	2.61	
Munich	Aug. 12, 1873	30	4.04	Gordon.
Paris	Sept. 20, 1837	20	4.89	Bürkli,
Philadelphia	July 26, 1887	7	5.31	Weather Rev.
Posen	June 26, 1863	20	2.86	Hellmann.
Providence*	Aug. 6, 1878	36	5.83	Shedd.
Rochester	June 24, 1888	20	2.60	Kuichling.
St. Gallen	June 25, 1888	20	5 00	Schw. Bauz.
St. Louis	Aug. 15, 1848	75	4.04	Weather Rev.
Stuttgart*	July 23, 1883	3	5.93	Dobel.
Trier	June 17, 1856	60	2.90	Hellmann.
Washington	July 29, 1877	28	3.09	
Wermsdorf	May 9, 1867	15	4.99	Hellmann.
Zurich	Sept. 9, 1876	10	5.04	Bürkli.

† Doubtful.

It is not absolutely essential to determine these extreme cases of rainfall, since sewer sections are usually proportioned without regard to them; in fact, sewers corresponding to these quantities would be expensive, and the difficulties of keeping them in good condition would be great. On the other hand, too small sections result in a backing up of the water in the streets and catch-basins. In some respects this would be advantageous (the velocity on the surface of the water is greater than at the bottom, and hence a full sewer will discharge quicker than under other conditions), but the pressure against the walls will be so great that there is a constant danger of rupture. The sanitary effects of full sewers are very bad; the ground becomes wet and the sewage backs up in the house drains. Although this condition of affairs is usually of short duration, in those storms noted in the foregoing table by an asterisk the overflow proved highly deleterious, both

to health and comfort. Neglect to provide drains large enough to carry off the usual rains results in a decline in the value of the land in question, and causes the tenants in the neighborhood to move. On this account, BÜRKLI recommends for Swiss cities, a sewer capacity corresponding to a fall of from 1.79 to 2.86 cu. ft. per second per acre. In Germany, from 1 to 2.14 cu. ft. would probably be a fair allowance. English and American engineers usually assume 1 cu. ft., although in America heavier rainfalls occur in periods ranging from 1 to 4 years. It is probable that the practice in the United States will tend toward a larger figure, as the people become less willing to put up with the inconvenience of overflowed streets and cellars.

Wherever records of the rainfall have been kept in a scientific manner, it is very easy to come to a decision regarding the capacity necessary to carry away the storm water. In such a case the records should be examined, and all notes of precipitations exceeding, say 0.70 cu. ft., plotted to scale, using the duration in minutes of the maximum fall as an abscissa and the fall itself as an ordinate.* In this way a collection of points is formed, the upper limit of which gives the relation between maximum rate of precipitation and its duration for the place in question. Prof. NIPHER found that this upper boundary for St. Louis was an hyperbola. KUICHLING found that in Rochester the locus was formed by two intersecting straight lines, the one at the left of the diagram being much inclined, the other less so. Such results are of doubtful value unless the observations are very numerous. The best plan is to draw a horizontal line between the mass of the points and those more scattered, and take this line as the basis of calculation.

The rain water is disposed of in three ways: part evaporates, part percolates through the soil, and part flows away over the surface. For sewerage purposes, it is very desirable to know the relation between the first two and the last, but data are usually wanting on this point. In order to determine the amount of water reaching the sewers it is necessary to have self-registering rain gauges and water-meters of some kind in the drains. The apparatus should be distributed over the city so that the amount of discharge from each district can be determined. The first scientific work of this sort was probably done by KUICHLING, at

* The fall itself may be used if stated as cu. ft. per sec. per acre, otherwise the *rate* of fall as inches per hour should be used. A rate of 1 inch per hour corresponds to very nearly 1 cu. ft. per sec. per acre.

Rochester, N. Y. At other places the estimates are to be regarded as of a more or less approximate nature.

The conditions influencing the division of the rainfall into the above-mentioned three parts are as follows :

a. The amount of moisture in the air and ground. If at the beginning of a storm the air and ground are already saturated from previous rains, the amount of evaporation and absorption will be small while the surface discharge will be large. The same holds true for continued rains ; the percentage of surface water compared with the total fall will gradually increase for some time. The sand and gravel walks in gardens and parks illustrate this point, since these materials absorb the water rapidly at first, but soon become thoroughly soaked.

b. The relation between the impervious area (roofs, paved streets and courts) and the more porous surfaces (gardens and parks). For drainage purposes, the ratio of the storm sewage to the total precipitation can be assumed as the same as that existing between the impervious and the total area. In this connection it is of interest to note that KUICHLING has demonstrated that the percentage of precipitation reaching the sewers is a constant with all variations of rainfall.

c. Size and slope of the area under consideration. The greater the area and the more level its surface, the greater will be the time necessary for the rain to reach the sewers, and the greater the opportunities for evaporation and absorption. Hence the percentage of water reaching the sewers will gradually increase during protracted storms until the farthest areas begin to discharge their precipitations into the system. If the rain is of short duration, such as those given above, it is probable that the storm will cease before the outer districts begin to discharge, unless the total area is small. In large districts it is usually true that the flow in sewers first begins to increase with any rapidity when the storm has begun to abate in intensity.

Numerical data concerning the amount of water conducted away in drains are as follows : In England from 0 to 70 per cent. of the fall reaches the drains, averaging about 50. In different districts of London from 53 to 94 per cent. has been registered. It required from 3 to 4 times the duration of the rain to carry off the water, and the maximum flow per second in the sewers rose as high as 2.4 times the average obtained by dividing the total effluent due

to the storms by the number of seconds of flowing. Hence it will be seen that the necessary capacity will be $\frac{0.5 \times 2.4}{3.5} = \frac{1}{3}$ of the rainfall per second.

In general, it is customary to assume the greatest quantity of storm water at $\frac{1}{6}$ to $\frac{1}{2}$ of the total fall, according to the nature and extent of the area drained and its configuration. BÜRKLI fixes the greatest necessary capacity at 0.86 cu. ft. per second per acre, but this is a mere approximation, obtained by using but one coefficient for the conditions expressed under *a*, *b* and *c* above. In more exact calculations, although it is difficult to obtain a satisfactory reducing factor for *a*, a coefficient should be given for *b* and *c*, so that the form of the equation for the maximum flow becomes

$$A = x\, y\, R\, F$$

where A is the quantity of effluent, R the precipitation per acre, both in cubic feet per second, F the drainage area, in acres, x a coefficient expressing the ratio discussed in *b*, and y a coefficient discussed under *c*.

As regards x, it is simply the ratio of impervious surfaces to the whole area. When this is difficult to determine, especially in districts not yet developed, various expedients are adopted. This ratio is from 0.25 to 0.5 in villages, from 0.5 to 0.7 in towns and 0.7 to 1 in cities. The means of these sets of values, 0.4, 0.6, and 0.8, are probably accurate enough in designing sections for future as well as present conditions. But it is to be noticed that the use of a single coefficient for a whole city would make many sewers unnecessarily large and expensive.

For American conditions, KUICHLING gives the following relations for heavy and impervious ground, in places having a variable density of population :

Population per acre.	Population per sq. mile.	Heavy ground.	Impervious ground.
25	16,000	21.5 per cent.	25 per cent.
32	20,700	25.0 " "	33 " "
40	25,600	27.5 " "	43 " "
50	32,000	28.0 " "	55 " "

The sand and gravel walks are assumed to be semi-heavy, while roofs and paving is regarded as impervious. Only the last column of figures is of use in determining x.

A number of different plans have been proposed for determining the value of y.* The three leading German formulas are graphically given in Fig. 2, which represents the curves

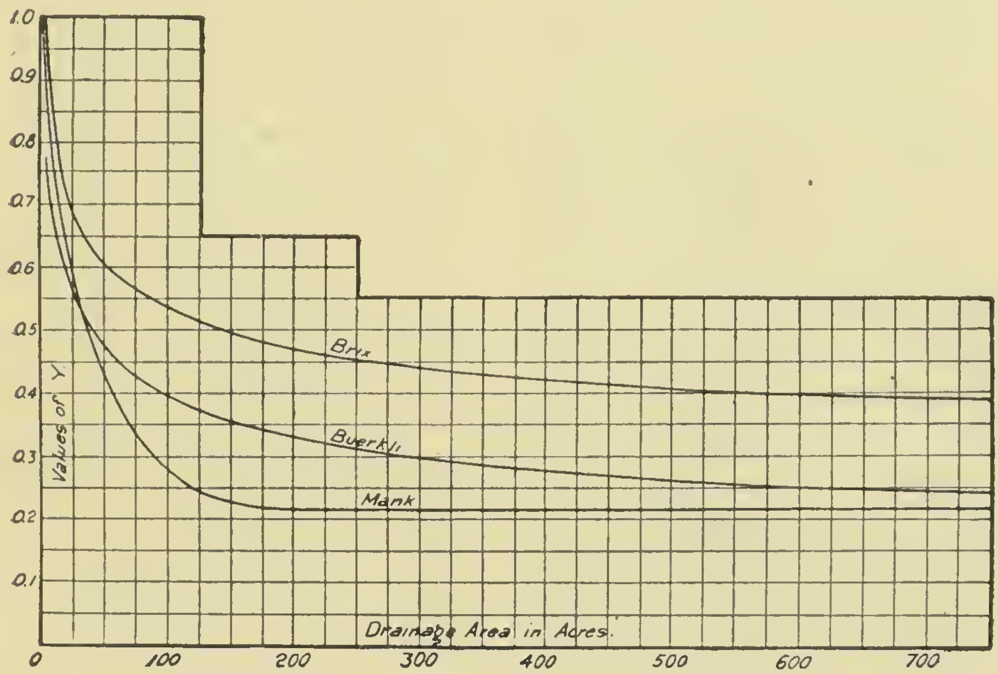

FIG. 2 —DIAGRAM SHOWING VALUES OF THE COEFFICIENT OF RETARDATION.

of BÜRKLI, MANK and BRIX for determining the coefficient y with approximate accuracy at a glance.

According to KNAUFF, the maximum quantity of storm effluent from impervious surfaces is from 40 to 80 per cent. of the rainfall ; from 50 to 70 per cent. in courts and squares, from 40 to 50 per cent. on flat, and 60 to 80 per cent. on steep roofs. In general, these figures must be regarded as rather low for small areas, since the point of saturation is soon reached.

The following table gives the figures used in calculating the sewerage systems of a number of European cities. It will be noticed that a distinction is drawn between sewers without or above relief outlets and those in which such openings occur. The difference between these sets of figures gives the capacity of the outlets.

* The remainder of this chapter is considerably condensed from the original German text, to which the reader is referred for a more complete discussion of the subject. See page 280 et seq.

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TABLE III.—ESTIMATED RAINFALL AND EFFLUENT IN EUROPEAN CITIES. CUBIC FEET PER SECOND PER ACRE

City.	Mode of estimating.	Above outlets. Rain fall.	Above outlets. Coefficient.	Above outlets. Effluent.	Below outlets. Rain fall.	Below outlets. Coefficient.	Below outlets. Effluent.
Berlin	Average population	0.91	⅓	0.30			
	Districts with parks	0.91	1-6	0.15			
	Average of 5 districts			0.28	0.039*	½	0.015*
Brunswick	Outlying districts	0.83	½	0.41			
Breslau	Lateral sewers	0.26	⅓	0.09			
	Main "	0.13	⅓	0.04			
	Outlet "						0.021*
Chemnitz	Varies with population and surface inclination	1.00	Mank's curve.	{ 0.24 0.71			{ 0.029 0.050
Danzig	Thickly inhabited districts	0.51	½	0.26	0.021*	½	0.011*
	Thinly inhabited districts	0.51	⅓	0.17	0.021*	⅓	0.007*
Dortmund	Small sewers	0.36	⅔	0.24			
	Average "	0.36	½	0.18			
	Outlet "	0.36	⅓	0.12			
Dusseldorf	Average	1.61	⅓	0.54	0.048	½	0.024
	Flood area (roof drainage)			0.27			0.012
	Railway stations			0.14			
Emden	Lateral sewers	0.91	⅓	0.30			
	Main "						0.040
England	Many cities	1.00	½	0.50			
Frankfurt	Varies with size			0.17			
	Slopes & pop.			0.43			
	Intercepting sewers						0.040
Freiburg	Thickly peopled distr's.			0.57—0.71			
	Thinly peopled districts			0.29			
	New designs	2.57	Mank's curve.	$y \times 1.54$			
Hamburg		1.11	½	0.55	0.040	⅔	0.027
Karlsruhe		0.51	½	0.26			
Cologne	Main sewers, old city	1.00	3-5	0.60			0.040
	Main sewers, new city	1.00	about ⅓	0.36			0.040
	Lateral sewers old city	1.00	4-5	0.80			
	Lateral sewers new city	1.00	about ½	0.49			
Kœnigsberg	Main sewers	2.90	¼	0.73	0.514	¼	0.129
Linz				0.79			
London	Varies with size and density of population	1.00	⅓--½	0.33—0.50			
Liege		0.87	⅓	0.29			
Mainz		1.59	½	0.79			
Mannheim	Center of city	1.79	Burkli's curve.	$y \times 1.2$			
	Suburbs	1.79	" "	$y \times 0.9$			
	Very open suburbs	1.79	" "	$y \times 0.6$			

TABLE III.—CONTINUED.

CITY.	Mode of estimating.	Above outlets. Rain fall.	Above outlets. Coefficient.	Effluent.	Below outlets. Rain fall.	Below outlets. Coefficient	Below outlets. Effluent.
Munich	Suburbs......	0.64	1·5—⅙	0.13—0.32	......	....	....
	Trunk sewers.	0.64	about ⅓	0.21	......	....	0 05-0.111
Nuremburg	Varies with size of dist...	0.51	⅙—½	0.17—0.25	......	....	....
Paris.........	Trunk sewers.	1.79	⅓	0.60	......	....	....
Pest..........	Trunk sewers.	1.00	0 15—0.3	0 .16- 0.3	......	....	....
Stettin.......	....	0.51	½	0.26	.....	....	....
Stuttgart	Main sewers..	......	....	0.17—0.24	.....	....	....
	Trunk "	......	....	....	0.179	0.27	0.049
Vienna.	Single sewers, old system..	1.00	⅜	0.38	......	....	....
	Trunk sewers, new system..	0.78	⅓	0.26	......	....	0.040
	Cultiva'd land	0.78	1-6	0.13	......	....	....
Wiesbaden...	Dense population	1.39	Brix's curve.	$y \times 1.04$	......	....	0.037
	Thin population...... ...	1.39	" "	$y \times 0.77$	......	....	0.023
	Suburbs	1.39	" "	$y \times 0.51$	....	....	0.009

NOTE.—These figures were used in designing the several systems noted, and must not be taken as giving the actual rainfall or effluent. The figures marked with an asterisk were used in calculating the pumping plant.

[A complete translation of what Prof. Baumeister has to say on the subject of "run-off" will be found in the appendix.—ED.]

CHAPTER IV.

CHARACTER OF WASTE AND RAIN WATER AND SEWAGE.

The waste water is in part pure, such portions as are supplied from baths, wells, boilers, etc., and in part polluted with sand,* soap, kitchen refuse, and the waste products of manufacturing establishments. Rain water which falls after a period of dry weather washes more or less matter from the streets into the sewers, and the amount of impurities depends largely on the manner of cleaning the roads and highways, and the extent of the traffic. That such impurities are quite considerable is at once evident to the senses when an old sewer is being cleaned. Careful and extended researches by EMMERICH show that even the waste water from sinks and that used in cleaning floors or sprinkling streets, will become poisonous if allowed to stand for some days.

Examinations of waste and rain water as it flows into the sewers are of little value on account of the great variations in its character. As an extreme case, Parisian sewers are interesting; it has been found that at the beginning of a heavy rain or a thorough street cleaning the water in the gutters had a much higher quantity of organic matter suspended and dissolved in it than the sewage.

Analyses of sewage from different cities in which the relative proportions of excrement, waste and rain water vary considerably, are of much greater interest, since a comparison of the data will give the influence of each component. But the proportions in which the different parts of the sewage are added are known in but few cities; especially lacking are data concerning the disposal of excrement. The following table is very instructive on account of its accuracy in this respect.

The figures in the first column give the proportion of excrement which passes into the sewers. In London, Berlin and Danzig nearly all the matter is so carried away, about 70 per cent. in Frankfurt, and 80 per cent. in Zurich. In English cities with mixed systems, the amount of excrement removed from the

* In most German towns large quantities of sand are used in the household for scouring purposes and on the floors.

houses is fairly well known, consequently the remainder, some 40 per cent., must pass into the drains. The figures for Paris were determined in this way also. The ratio in Munich is probably

TABLE IV.—ANALYSES OF SEWAGE.

CITY.	Proportion excreta found in sewage.	Cubic feet sewage per capita daily.	Components: grains per cubic foot.					Nitrogen, grains.	
			Suspended.		Dissolved.		Total.	Per cubic foot.	Per capita daily.
			Inorganic.	Organic.	Inorganic.	Organic.			
Average of 16 English cities with water closets.....	1	6.36*	105.75	89.59	315.51		510.85	37.15	231.5
London, average...	1	7.06*	154.7	112.75	281.86		549.31	34.96	246.9
London, sudden storms............	1	....	798.84	224.62	275.75		1299.21	32.34	......
Berlin, average.....	1	3.53*	91.83	197.96	221.12	108.81	622.72	30.59	108.
Danzig..............	1	6.36*	94.39	165.62	218.06	74.73	552.80	28.41	185.2
Frankfurt, dry weather...........	0.7	3.53	33.21	31.46	250 4	124.55	439.62	20.54	77.2
Frankfurt, moist weather...........	0.7	11.30	348.29	88.71	105.01	109.25	651.26	29.28	324.1
Frankfurt, settling basins............	0.7	6.36*	164.75	401.6	158.07	253.9	978.32	50.26	324.1
Zurich, average....	0.8	14.13	15.73	40.23	130.23	79.53	265.72	49.82	694.5
Average of 15 English cities with mixed sanitary arrangements.....	0.4	5.30*	77.79	93.08	360.09		530.96	31.9	169.8
Paris, average......	0.3	5 30*	458.85	225.06	249.96	112 75	1046.62	19.67	108.
Wiesbaden..........	0.2	12.18	17.48	14.86	777.86	406.41	1216.61	10.05	123.5
Munich.............	0.2	16.42	17.48	34.96	157.76	83.03	293.23	.....	......
Bremen.............	0	....	249 53		448.63		698.16	26.22	......
Essen..............	0	6.71*	45.89	93.08	267 88	100.51	507.36	46.32	308.6
Halle, minimum....	......	....	43.7	43.7	305.9	131 1	524.4	26.22	......
" maximum..	......	....	874.	611 8	1573.2	568.1	3627.1	184.05	......
" average......	......	3.18	262.2	218.5	524.4	305.9	1311.	61.18	200.6

NOTE.—One gramme per cubic meter is equivalent to 0.437 grains per cubic foot. The number of micro-organisms varies between 30 and 100 millions per cubic meter of sewage.

considerably different now from the tabulated quantities, which are accurate for the condition of the sewage existing a short time ago.

In the second column are the quantities of sewage per day per person, those marked with an asterisk being the average for the year. The examinations were made at the outlets and generally at different hours of the day in order to eliminate the local and hourly variations as much as possible. To show the variation that sometimes exists, the maximum, minimum and average figures are

given for Halle. The figures for London were calculated from 21 observations extending over several months ; those for Berlin are the average of three years' examinations ; the Danzig data are the means of tests made during one rainy and six dry days, while the Paris figures are taken from records made during the years 1868–77 inclusive. The figures for the other cities are for dry weather, but they are fairly true for the annual average. The influence of rains, taken annually, is not particularly great as a rule, and it is very seldom that the annual precipitation equals or exceeds the amount of waste water. Where the excess of rain in the sewers passes off through overflows, it is certainly safe to assume that the carrying water and sewage are of the same character. . Examinations in London show that an increase in the amount of sewage by rains, instead of diluting renders it still more impure by the addition of sand and other street refuse. It is the usual practice in England to consider this street water of the same degree of impurity as the sewage in dry weather.

It must be noticed, however, that ground and flushing water are relatively free from organic matter and nitrogen. About a third of the sewage in Zurich and a half in Munich is ground and flushing water. The analyses for Wiesbaden are based upon a mixture of 2 parts brook water and 1 part sewage. The actual amount of organic matter is, therefore, about three times that given in the table. The large amount of inorganic matter is due to the mineral character of the carrying water.

The figures in the last column are of especial value as proving the statement sometimes met with that the actual effect of excrement in sewage is less than that determined on theoretical grounds. Both the Prussian and English government engineers have long held this view.

The table shows that the character of the sewage depends not only on the amount of dilution, but also on the habits of the people, the manufacturing establishments and the plan of the sewerage system, whether the effluent flows away directly or is some time in the sewers, whether or not deposits are formed, and, if they are formed, on the frequency of their removal.

CHAPTER V.

Shape and Material of Sewers.

The minimum height of a sewer that will permit the passage of a laborer is usually taken at from 3 ft. 3 ins. to 3 ft. 6 ins., although Hamburg, Frankfurt, Stuttgart and Munich allow 3 ft. In many cities the accepted practice calls for all sewers to be large enough for a man to enter and clean them ; Hamburg, Linz, London, Magdeburg and Wurzburg have such regulations. Formerly Budapest, Prague, Paris and Vienna required even the house connections to fulfill these conditions, but the rules are not enforced.

From another point of view it will be seen that there is little advantage to be derived from increasing the dimensions of a small drain above the hydraulic requirements, unless the increase will be inexpensive. But when a certain size has been reached it will be found that the excavation forms the chief item of cost, and it makes comparatively little financial difference whether the section is 1 ft. 6 ins. or 3 ft. high, while the advantages of increased capacity and better circulation with the latter size are considerable. This limit for very small sections is 2.08 ft. in Berlin and Danzig, 1.64 in Dusseldorf, 1.54 in Breslau, 1.48 in Munich, Stuttgart and Karlsbad, 1.31 in Liege and 1.25 in the very low sewers of Frankfurt. Sewers between these limits and a height allowing the passage of a man are very rare. This view of the matter is all the more allowable from the fact that such quite small sections are self-flushing and can be laid with little expense, so that the cost of laying a similar parallel line, if the amount of sewage should ever call for an increased capacity, would be small.

The cross section should always give the greatest possible hydraulic mean radius (the hydraulic mean depth of Rankine), and hence the greatest possible velocity. The mean radius is the quotient of the section of the water divided by the wetted perimeter. Where the sewage varies considerably in volume the egg-shaped section is the most advantageous. Fig. 3 is a diagram of

this form; the figures are the multiples of the width, which is taken as unity. The section designed by PHILIPPE, and given in Fig. 4, is better adapted for very small quantities of water, while Fig. 5 represents a shape also adapted for small quantities, and at the same time very easy of access for cleaning. In Linz the height is taken at twice the width, except for the largest sewers. A very good form as regards the comfort of the laborers is shown in Figs. 6 and 7. The sections for trunk sewers where the depth of water is fairly constant are sometimes designed as in Figs. 8 and 9, which show a very flat curve for the sole.* Occasionally the shapes given in Figs. 10 and 11 are employed where a con-

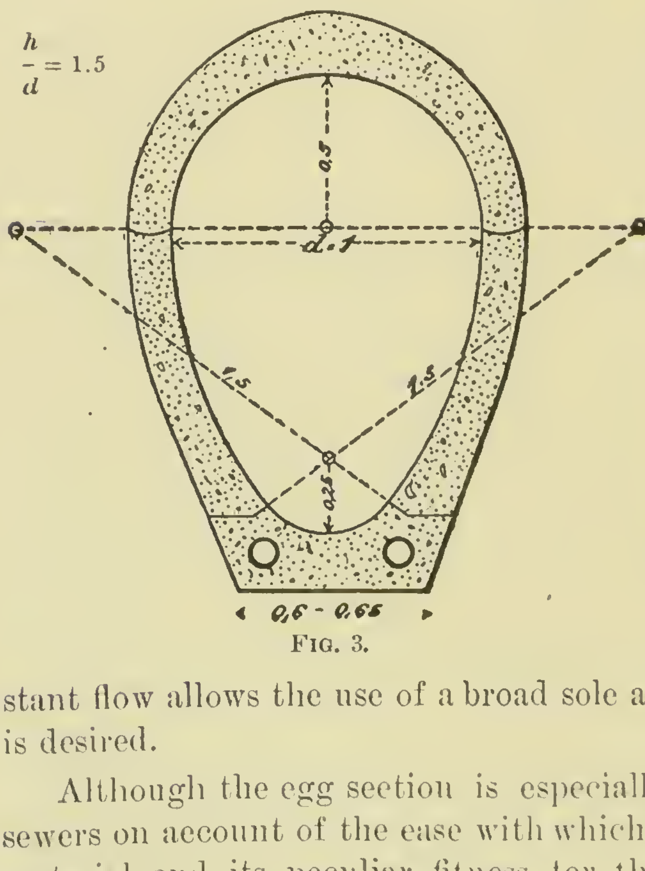

FIG. 3.

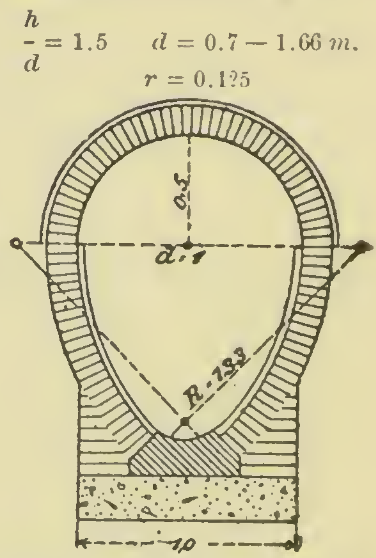

FIG. 4.—SEWER SECTIONS AT LIEGE.

stant flow allows the use of a broad sole and a considerable height is desired.

Although the egg section is especially adapted to secondary sewers on account of the ease with which it can be built from any material and its peculiar fitness for the variable quantities of water which flow through such sewers, nevertheless the German engineers usually prefer the circular section in such cases on account of the ease with which it can be cleaned by brushes. Moreover, in large trunk sewers which never run dry, the egg-shape is of little advantage and the gain in wet section at the same height of water by using a circular form of equal area is considerable. On this account the egg section is usually restricted to heights

* Sole = Invert.

between 1.6 and 5.2 ft., although all sewers in Dresden, Mainz, Cologne, and Wiesbaden are of this shape.

Where large quantities of water must be carried and a low section is desired, the sewers shown in Figs. 12 and 13 are satisfactory. The forms shown in Fig. 14 are used in England. But if allowance must also be made for carrying small bodies of water, a secondary section must be added. This is particularly the case where small brooks are utilized in the sewerage system. The brook shown in Fig. 15 was at one time partly arched, and

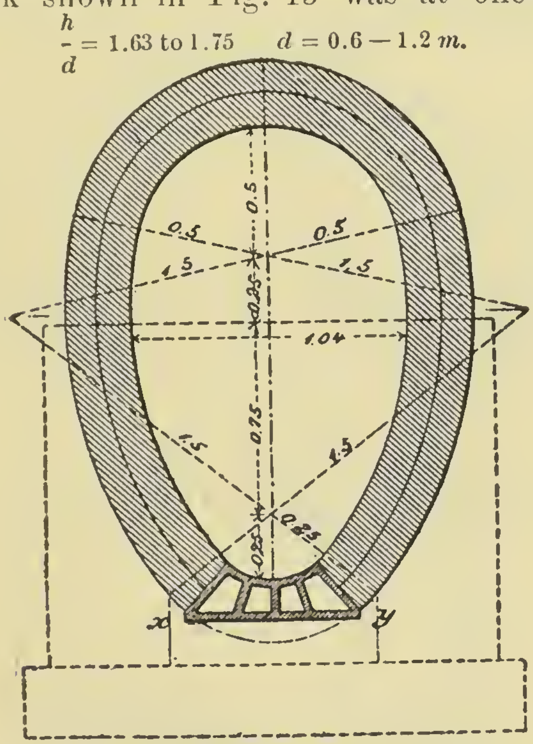

FIG. 5.—SEWER SECTIONS, MAINZ, COLOGNE AND WIESBADEN.

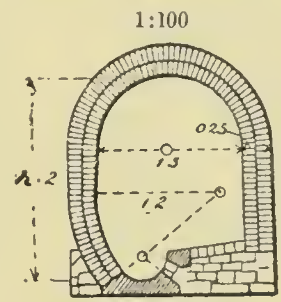

FIG 6.- SECTION IN WIESBADEN; h = 2 meters.

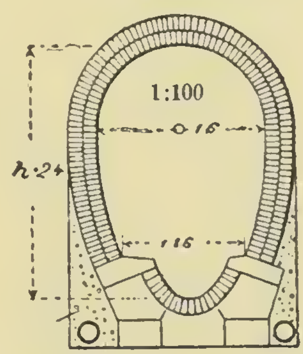

FIG. 7. — SECTION IN STUTTGART; h = 2.4 meters.

partly open (x) or provided with a low wall (y) to serve as the bottom of a proposed arch. Figs. 16 and 17 show additional sections of this kind. In Vienna, the trunk sewers have a nearly flat sole, since it was found that the curved form was more rapidly worn away by the sand in the sewage. In Charlottenburg sections, a triangular sole with glazed sides is placed at the bottom of an egg sewer in order that the deposits may be reduced to a minimum. The Parisian profile, shown in Fig. 18, was designed to give the most easily cleaned section, and also to afford a subway for water, gas, telegraph and other pipes, thus doing away with torn-up pavements.

In order to diminish the probability of the sewers being stopped by large objects lodging within them, many cities have adopted minimum widths for drains and sewers below which it is not allowed to go; between $7\frac{3}{4}$ and $13\frac{3}{4}$ ins. for drains from large lots; between 4 and $4\frac{3}{4}$ ins. for pipes from houses. It sometimes happens, however, in endeavoring to have drains of a sufficient size, that the pipes run dry very often and deposits are formed.

$\frac{h}{d} = 1.5 \; d = 0.8 - 1.2 \; m$

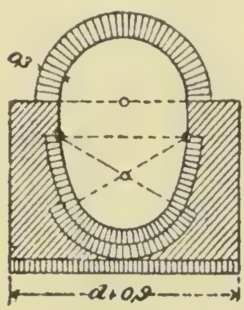

FIG. 8.—SECTION AT VIENNA.

$\frac{h}{d} = 1.2 - 1.4 \quad d = 1.2 - 1.8 \; m.$

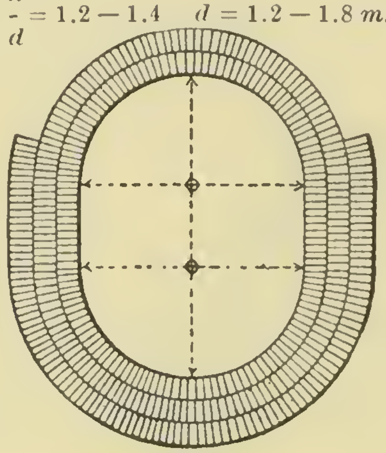

FIG. 9.

$\frac{h}{d} = 1.5$

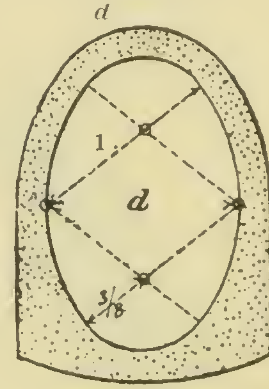

FIG. 10.

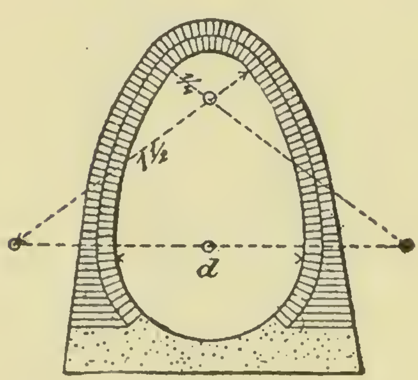

FIG. 11.

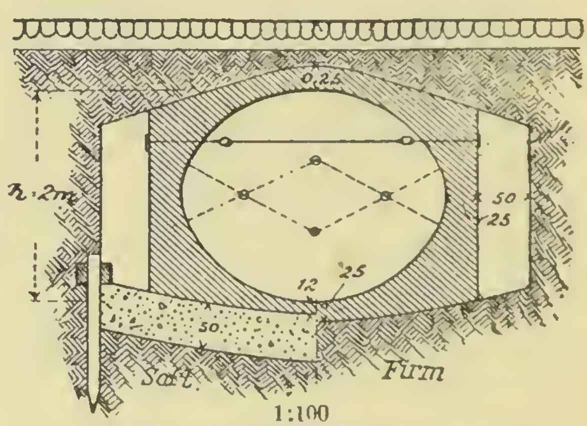

FIG. 12.—SEWER SECTION, BREMEN.

Small sewers would be cleaner; the wide sections remain open longer, but the deposits of sediment more certainly occur.

Where water-closets and kitchen sinks are connected, the pipes should not fall below 3 to 4 ins. on any account, as they are particularly liable to stop. For house connections, 4 to 6 ins. will usually suffice. The objects which would close a drain of this size should never be thrown into them, and it is much better for them to clog the pipes of the person committing such an act than to pass into the secondary sewers where they will be deposited and become more difficult to remove.

If we let d equal the inside diameter of a drain, p the specific pressure on the sides, k the specific strength of the material, then the thickness of the sides will be $t = d\,p \div 2\,k$. This formula

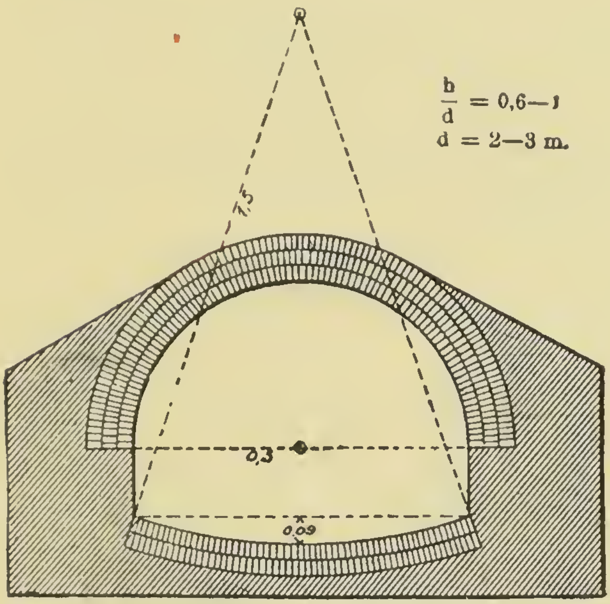

FIG. 13.—SECTION OF BERLIN SEWERS.

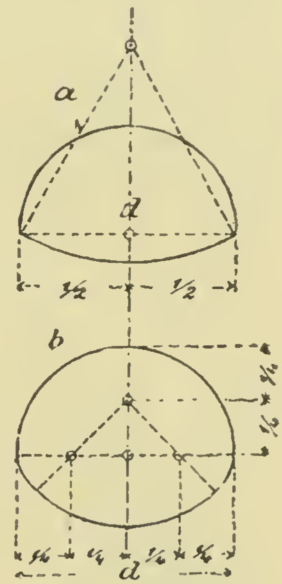

FIG. 14.—ENGLISH SECTIONS.

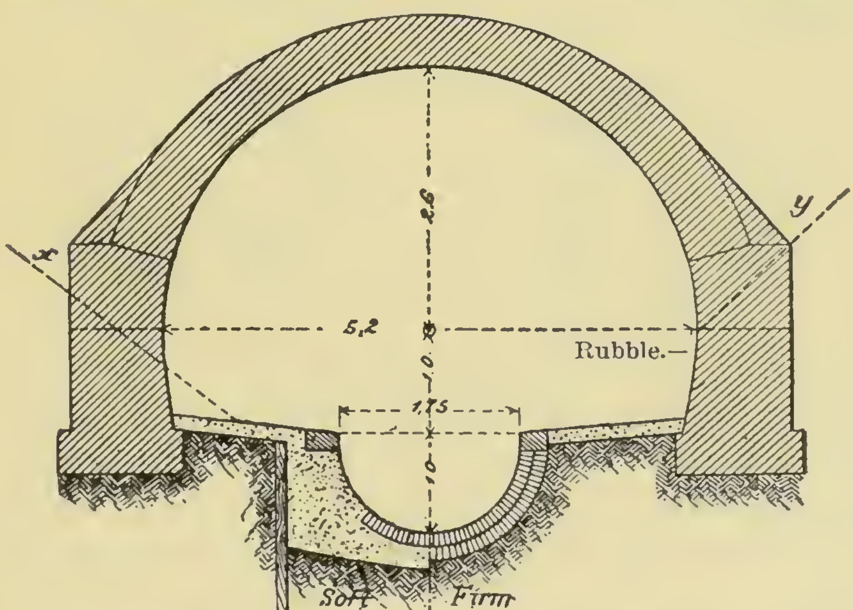

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FIG. 15.—SEWER SECTION IN KARLSRUHE.—DIMENSIONS IN METERS.

can also be used in calculating the thickness of sewers subjected to heavy pressures due to passing wagons, provided a proper allowance is made for the additional load. Sections of large sewers must always be designed with a careful regard to the resisting

power of the material in which they are laid. As a general thing, however, the thickness of the walls is settled by empirical rules resulting from a comparison of sections that have proved satisfactory in practice.

The different materials used in sewerage works modify the sections adopted and the nature of the foundations used in a marked manner.

1. *Cast-iron.*—This material is used in streets subject to tremors from vehicles, in bad ground with pile foundations, and

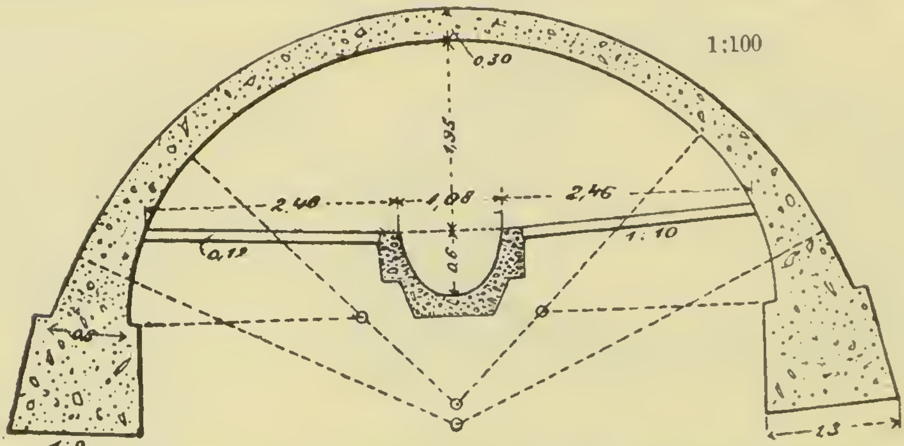

Fig. 16.—Sewer Section in Altenberg.—Dimensions in Meters.

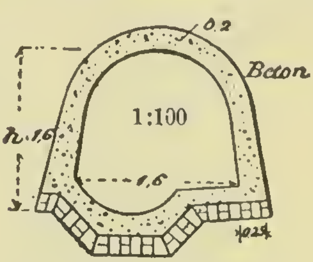

Fig. 17.—Maulbronn.

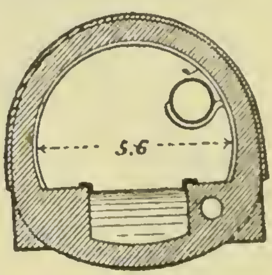

Fig. 18.—Paris.

especially for house connections subject to inside pressure, which occurs when the mouth of the connection is below the crown of the street sewer into which it empties. Iron should always be used for exposed house drains. The thickness of the metal may be thinner than for water pipes under high pressure, but is often too thin to allow for imperfections in casting and the effect of rust. Holes and cracks are more unpleasant than a slight increase in the original outlay. In Germany, pipes of 2, 4 and 6 ins. diameter have thicknesses of 0.28, 0.35 and 0.47 ins. respectively. In Frankfurt, 0.39 ins. for approximately horizontal, and 0.32 ins. for upright pipes, are average values, although 0.24 ins. occurs in the thinnest sections. Pressure tests are valuable and

are easily made by filling all the connections with water. Rust must be carefully avoided by the use of varnish, tar, or by galvanizing, and the joints should be made with tarred oakum and lead, or with cement.*

2. *Clay pipes.*—It is important that they should be burnt to the vitrifying point and be properly glazed. A smooth surface is especially desirable in the drains which are rarely flushed. In 1881, the German manufacturers adopted the following dimensions (1 centimeter equals 0.4 in. and 1 kilogramme a meter equals 2 pounds a yard, approximately):

Diameter, cm	10	20	30	40	50	60
Thickness, cm	1.2–1.6	1.9–2.3	2.5–2.8	3.1–3.4	3.5–3.8	4.0–4.3
Weight, kg. per meter	16	32	50	75	100	140

These pipes are as thin as it is possible to make them and retain a proper factor of safety. They vary from 2 to 4 ft. in length and have sockets about 3 ins. deep, which are calked with tarred hemp or rolls of clay or cement. Sometimes clay is forced into the joints and coated with cement. There are various devices for aiding the removal of pipes once laid, such as making part of the sockets like rings, and movable along the drain. Tests should be made of the strength of the material, the absorbing power (in 24 hours never more than 3 per cent.), glazing and evenness of burning. Clay drains more than 20 ins. in diameter are liable to be badly formed and are expensive; egg-shaped sections are also liable to lose their proper form in burning.†

3. *Brick Work.*—This is laid in rings or courses about 4 ins. thick, and hence cannot be usually adapted to the exact thickness determined by calculation. Experience teaches that one ring is sufficient for sewers up to 3 ft. in diameter, 2 rings up to about 6 ft., while 4 rings have been used for 9-ft. sewers in Hamburg, and 12-ft. sewers in London. The same number of courses is usually continued round the whole section. In very soft ground the sides are strengthened and the foundations enlarged by brickwork or concrete. Voussoir brick are necessary in sharp curves, while alternate voussoir and plain brick are useful in curves of greater radius. The materials should be smooth and strong: in the more rarely wet sewers a poorer grade may be employed, but the soles should be made of the best vitrified brick, or of well glazed earthenware, as shown in Fig. 5. Sometimes cut stone is used in place of earthenware, as in Fig. 6, which shows a Wiesbaden

* Cement joints should never be used for pipes in or beneath the house.

† See note, page 282.

sewer with a basalt sole. In damp soils good work is rarely possible without the use of such blocks or a concrete invert similar to that shown in Fig. 11.

Brick work is always laid in the best cement mortar, and carefully finished within. Less durable, but unavoidable when brick are scarce, is a coating of cement over the surface of the sewer, extending from the bottom up the sides to the spring of the arch, as in Fig. 4. In Berlin, and some other places, the outside of the brick work is coated in a similar manner; here it is more durable, and increases the imperviousness of the sewer.

4. *Cut Stone.*—Where this material is cheap, good sections can be readily made from it. Fig. 19 represents two such types from Dresden, the first with a brick arch. The sides are coated with an even layer of cement from the spring of the arch downward, the arch being left rough as it is more rarely wet. In Wurzburg cut stone is used only for the soles; above comes brick work and the whole inside is coated with cement.

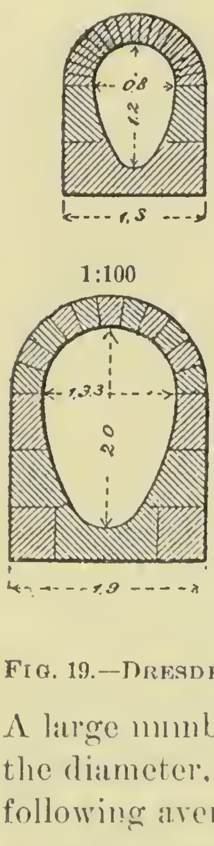

FIG. 19.—DRESDEN.

5. *Concrete.*—This is used in many places on account of its cheapness, smooth surface, and easy molding to the proper forms. It is formed from 1 part of cement to 4 to 7 parts of sand and gravel; the grains in the latter may be somewhat increased in size as the sections become greater. An average composition, which accords well with our present knowledge, is made up of 1 part of cement, 2 of sand, and 3 or 4 of gravel. A large number of examples show a thickness of from $\frac{1}{6}$ to $\frac{1}{4}$ of the diameter, in drains under 20 ins. diameter, up to $\frac{1}{5}$. The following average dimensions are instructive:

Diameter, inches............	8	18	24	31	39	47	55
Thickness, inches	1.6-2	2.4-3.2	3.5-4.7	4.7-5.9	5.9-7.1	6 7-7.9	7.9-9.1

In designing the Paris sewers from 5 to 8 ft. in diameter, $\frac{1}{8}$ of the latter was taken as the proper thickness, and recently, in large spans where the material can be properly disposed, the thickness has been reduced $\frac{1}{20}$, as shown in Fig. 18. This thickness is maintained around the whole section in both circular and egg sewers, save where base is broadened and thickened on account of loose or soft foundations. (See Figs. 3, 10 and 21).

The sewers of this material are constructed both out of and in place. When prepared out of the final position they are made circular up to 1.6 ft. and egg-shaped up to 3 ft. in diameter (see Fig. 20). The pipes are made in lengths of 3 to 4½ ft. with a plain mortise joint, which is filled with cement and sometimes finished outside with a cement coating. Large egg sections are made in 4 pieces, as shown in Fig. 3. Care must be taken that the backing has sufficient resistance to deformation when these compound sections are employed.

DYCKERHOFF and WIDMANN give the following dimensions for cement pipes; they have subjected the sections to careful tests and believe them to be perfect:

		4	6	8	10	12	16	20	24	31	39
Diameter, inches		4	6	8	10	12	16	20	24	31	39
Egg shape	Thickness, crown, inches	..	..	1.5	1.8	2 1	2.8	3.2	4.5	5 9	7.3
	" sides "	..	..	1.5	1.8	1.8	2.4	2.8	3.3	4.1	5.1
	" base "	..	..	1.8	2.2	2.2	2.8	3.2	4.1	5.5	5.9
	Weight, pounds a yard	..	..	182	266	314	552	1,042	1,350	2,072	3,200
Circular	" " "	44	72	120	176	232	384	542	742	1,164	1,610

Concrete sewers are made in place by pressing the materials between carefully excavated trench walls and wooden molds covered with thin metal plates, sometimes in two sections, as shown in Fig. 21, and sometimes in one complete form, as in Fig. 22. The molds are from 6 to 10 ft. long, supported at one end by the already finished sewer and at the other by proper frames.

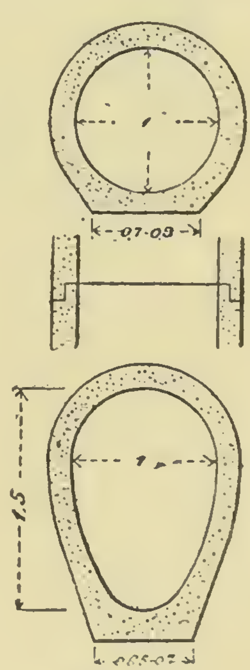

FIG. 20.

It is unnecessary to coat the inside with cement, since such a finish is no smoother than concrete carefully pressed against the metal surface of a mold, and, moreover, it is not possible to make a cement coating adhere properly to the walls. A considerable time, preferably several months, should elapse between the completion of the sewer and its use, since the resistance of the material to alterations in form and surface increases rapidly with age.

In comparing these two methods of using concrete, it will be seen that the sewers built in place are more apt to be porous and weak. The work is usually done rapidly, in order to lay as long a line as possible in the time given, and quick-setting cements are used. The tamping, moreover, is not so thoroughly done, es-

pecially in the lower part of the sections. In large sewers it is necessary to work in the trenches, which method has the advantage of producing a jointless drain.

While concrete sewers retain a more perfect shape than clay pipes, which warp in burning, or brick sewers with their many joints, nevertheless numerous examinations show that they become cracked and rough sooner and hence lose their apparent advantage. Possibly this is due to the poor character of the material so far employed and can be remedied by using more care. Still the brickwork sewers are ready for use sooner than those of concrete and are much easier to construct. On this account concrete walls and arches are sometimes built on stone or stoneware bases.

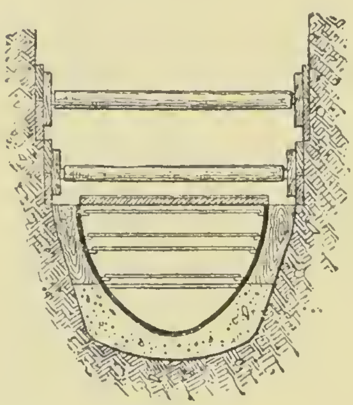

FIG. 21.

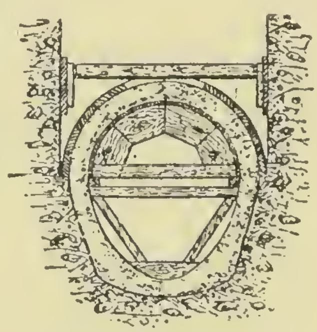

FIG. 22.—MUNICH.

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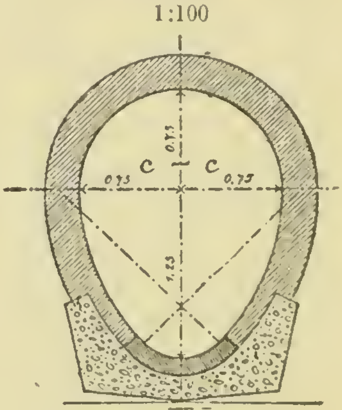

FIG. 23.—MUNICH.

6. *Mixed Masonry.*—Sewers have often been made from two materials ; inside as smooth and outside as cheap as possible. Such a combination is improper, however, on account of the difference in resistance of the material to heavy loads, which is apt to cause cracks. Many English sections are formed of an inner ring of brickwork and an outer shell of concrete. It is better to adopt the method employed in Vienna (see Fig. 8) where brick and rubble masonry is used. If the cement used is always the same, the setting of the compound sewer is practically uniform. Concrete foundations are sometimes finished off with masonry, as shown in Figs. 7, 15 and 23, and a uniform inside course thus obtained with increased bearing surfaces at the base.

Mention must be made of the danger to which sewers are exposed by acids from manufacturing works. Sometimes as much as 1 per cent. of nitric or hydrochloric acid has been found ; this

would quickly destroy cement and injure both natural stone and all iron work with which it came in contact. Only the glazing on clay drains can withstand these impurities, and on that account such pipes are recommended for house connections, where the acids are less diluted. Generally there is no such danger, and precautions need not be taken. Experience has shown that less than $\frac{1}{4}$ per cent. of acids do not affect the cement, and in London it was found that the brick work was first attacked.

In some places, hot water is regarded with disfavor. Berlin, for example, requires all the waste liquids to be below 95° Fahrenheit.

CHAPTER VI.

CALCULATION OF SEWERS.*

The usual formula for the steady flow of water is

$$v = c\sqrt{\frac{f\,h}{p\,l}},$$

where v is the average velocity, f the cross section of the water, p the wetted perimeter, h the difference in elevation and l the distance between any two points. If r, the hydraulic radius, equal to $f \div p$ and y, the rate of fall, equal to $h \div l$, are substituted in the above formula, we obtain

$$v = c\sqrt{r\,y}.$$

The coefficient c was assumed to be 50.9 by EYTELWEIN, and this value is still widely used on account of its simplicity. It has been found, however, that c varies with the roughness of the walls and the values given to r and y. Three sets of formulas are widely used for determining the size of closed pipes and sewers: the formulas of WEISBACH, used somewhat by English and American engineers; those of DARCY-BAZIN, employed in France, and those of GANGUILLET and KUTTER. The latter are in best accord with actual measurements and are expressed in three forms. The most general is

$$c = \frac{23 + \frac{1}{n} + \frac{0.00155}{y}}{1 + \left(23 + \frac{0.00155}{y}\right)\frac{n}{\sqrt{r}}}$$

and satisfies the following conditions: An increase of c with an increase of r, as well as with an increase in y in *small* streams; the decrease of c with increased roughness of the walls, and with an increase in y in *large* streams. If the members containing y are

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* All formulas and dimensions in this chapter are given in the metric system; formulas and diagrams in the usual system of measures will be found in the appendix.

See vol. VIII., Trans. Am. Soc. C. E., paper clxxv., by Rudolph Hering, for diagrams, etc.

"Flow of Water in Irrigation Canals, Ditches, Flumes, Pipes, Sewers, Conduits, etc.," by P. J. Flynn, for tables.

omitted on account of the small influence they have in the cases usually arising in sanitary engineering, the formula becomes

$$c = \frac{23 + \frac{1}{n}}{1 + \frac{23n}{\sqrt{r}}}.$$

Both these expressions, however, do not fulfill the condition that the influence of the roughness of the channel shall decrease as the hydraulic radius increases, a perfectly just condition as may be seen on considering any large river. In such a case it is plain that the nature of the river bed has very little effect on the velocity. On this account KUTTER proposed the following formula:

$$c = a - \frac{a\,b}{b + \sqrt{r}} = \frac{a\sqrt{r}}{b + \sqrt{r}}.$$

In this expression, a is assumed to be 100, b is a numeral varying with the nature of the channel between 0.12 and 2.44 in order to allow for every gradation between smooth cement and coarse shingle. KUTTER adopted 12 classes of roughness of channel. The usual materials of sewerage construction may be arranged under the first eight of these classes as follows:

Cement channel	I.- II.,	$b = 0.12–0.15$
Brick or dressed stone channels	III.- IV.,	$b = 0.20–0.27$
Rubble masonry channels	V.- VIII.,	$b = 0.35–0.72$

It must be remembered that these results were obtained by experiments with pure water in clean channels. The sewers of a city must, however, occasionally carry foul water in partly clogged pipes. Direct observations in Hamburg and Karlsruhe show that brick work corresponds to the sixth of KUTTER'S classes under such conditions, which will make b equal 0.45. Probably concrete, cement and dressed stone would have the same value, although glazed tile and iron might be in the fourth class.

In order to lighten the labor of calculating c, tables and diagrams have been prepared, the latter being the more useful. Fig. 24 gives, to a scale sufficiently large for practical purposes, the values of this coefficient for different hydraulic radii and classes of channel walls. Greater accuracy is not needed on account of the uncertainty as to the proper class to which any given sewer is to be assigned. The diagram shows the insufficiency of a single value, such as 50.9, for all conditions of channel and areas of

section. Moreover, a gradual rise of a horizontal line from 38 with the roughest to 63 with the smoothest channel, as BÜRKLI proposed, and as shown by *B B* in the figure, cannot be substituted for the curves. EYTELWEIN'S calculations would give too small results for the small sections and too large for the large, and hence materially increase the cost of a sewerage system. The assumption is sometimes regarded as sufficiently correct on account

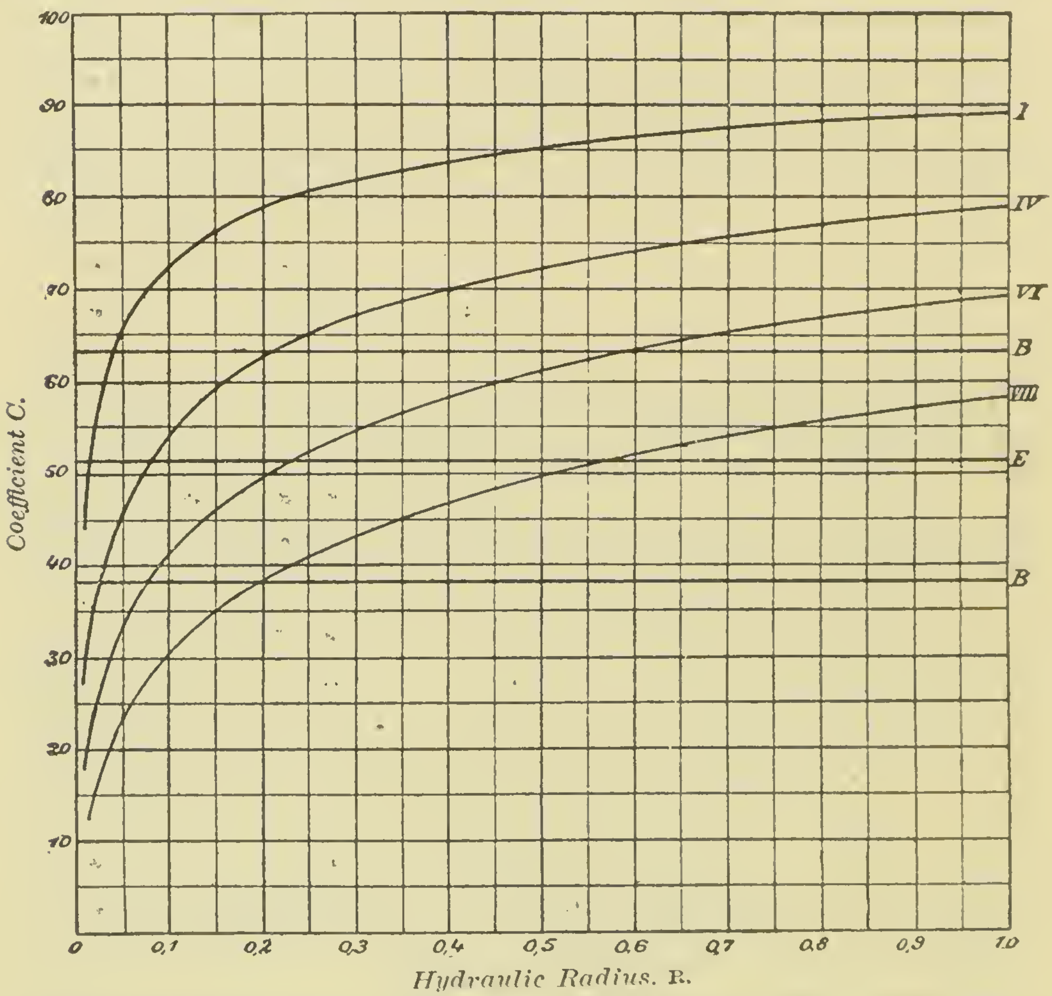


FIG. 21.—DIAGRAM GIVING VALUES OF *C* IN FORMULA FOR FLOW OF WATER.

of the uncertainty regarding the amount of rainfall and other data at the basis of all calculations. But a better result is obtained by KUTTER'S formula, and it should be employed for the same reasons that fairly exact computations are made in bridge designing, although only approximately exact loads are used and a large factor of safety is finally allowed.

Four variables must be fixed in designing sewers: *Q*, the volume of water; *y*, the rate of fall:* *v*, the average velocity; *d*,

* *y* = the rate of fall = the slope.

the diameter.* The remaining dimensions of a section are referred to the latter as a standard (see Figs. 3–5). These variables are related in the following manner:

$$v = c\sqrt{ry}, \quad Q = fv = cf\sqrt{ry}.$$

It is most convenient to refer all calculations to a full section, as follows:

	Circular section.	Egg section. Fig. 3.	Elliptic section. Fig. 10.	Flat section Fig. 14a.	Flat section Fig. 14b.
f	$0.785d^2$	$1.149d^2$	$1.172d^2$	$0.483d^2$	$0.665d^2$
p	$3.142d$	$3.965d$	$3.965d$	$2.618d$	$2.912d$
r	$0.25d$	$0.29d$	$0.296d$	$0.185d$	$0.229d$
v	$0.5c\sqrt{dy}$	$0.538c\sqrt{dy}$	$0.54.c\sqrt{dy}$	$0.43c\sqrt{dy}$	$0.478c\sqrt{dy}$
Q	$0.393c\sqrt{d^5y}$	$0.618c\sqrt{d^5y}$	$0.636c\sqrt{d^5y}$	$0.208c\sqrt{d^5y}$	$0.318c\sqrt{d^5y}$

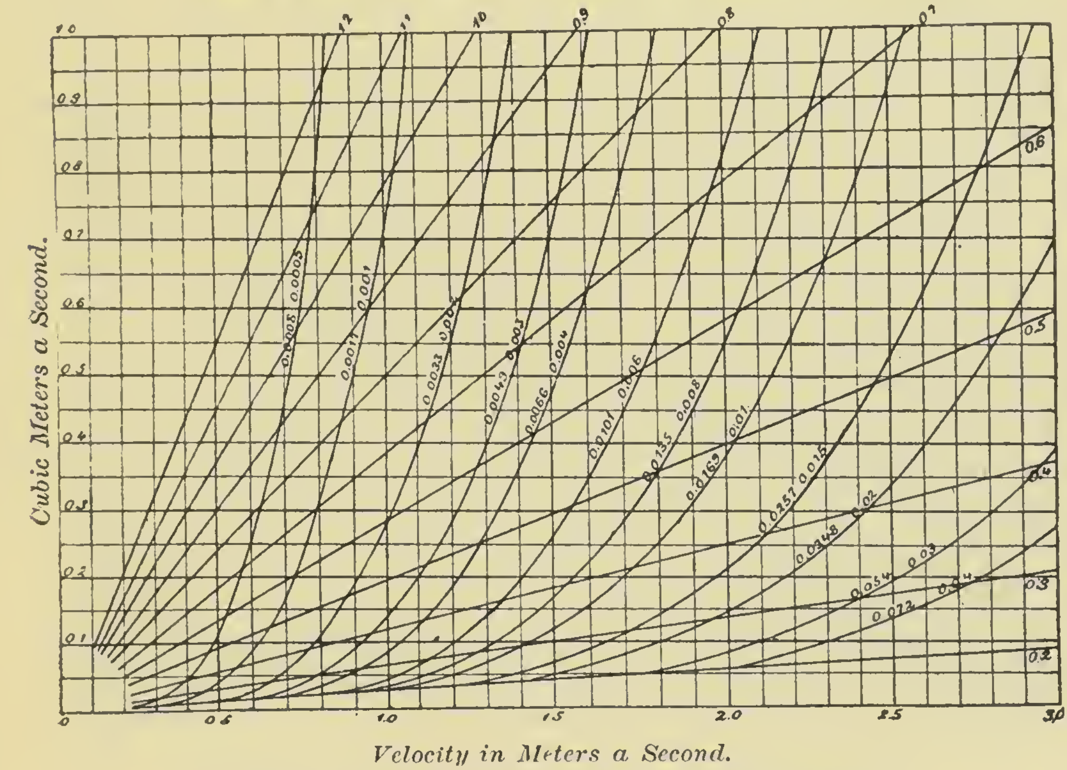


FIG. 25.—GENERAL DIAGRAM FOR CIRCULAR SECTIONS.

Generally Q and y are given, v and d are to be found, yet some easy method of finding any two of the quantities when the others are given is desirable. But this is somewhat difficult from the fact that c depends upon r, and hence upon d. In order to lighten this labor, many tables have been calculated, but graphical methods are to be preferred on account of the ease with which the relations between all the variables are to be seen at a glance. Figs. 25 and 26, the first for circular, the second for

* d = the horizontal diameter in these cases.

egg-shaped sections, are taken from larger diagrams, which may be found in the *Zeitschrift für Baukunde* of 1884. For every point on the diagrams, Q is the ordinate, v the abscissa, d the corresponding inclined straight line, and y the corresponding curve, the latter pair of values being obtained by interpolation, if necessary. The larger of the two numbers on the curves gives the fall y for the sixth class of the third KUTTER formula; the smaller number corresponds to the fourth class.

Other diagrams may be found in the works of the following authors:

a. GERHARD in the *Gesundheits-Ingenieur* for 1883. For circular sections; based on WEISBACH.

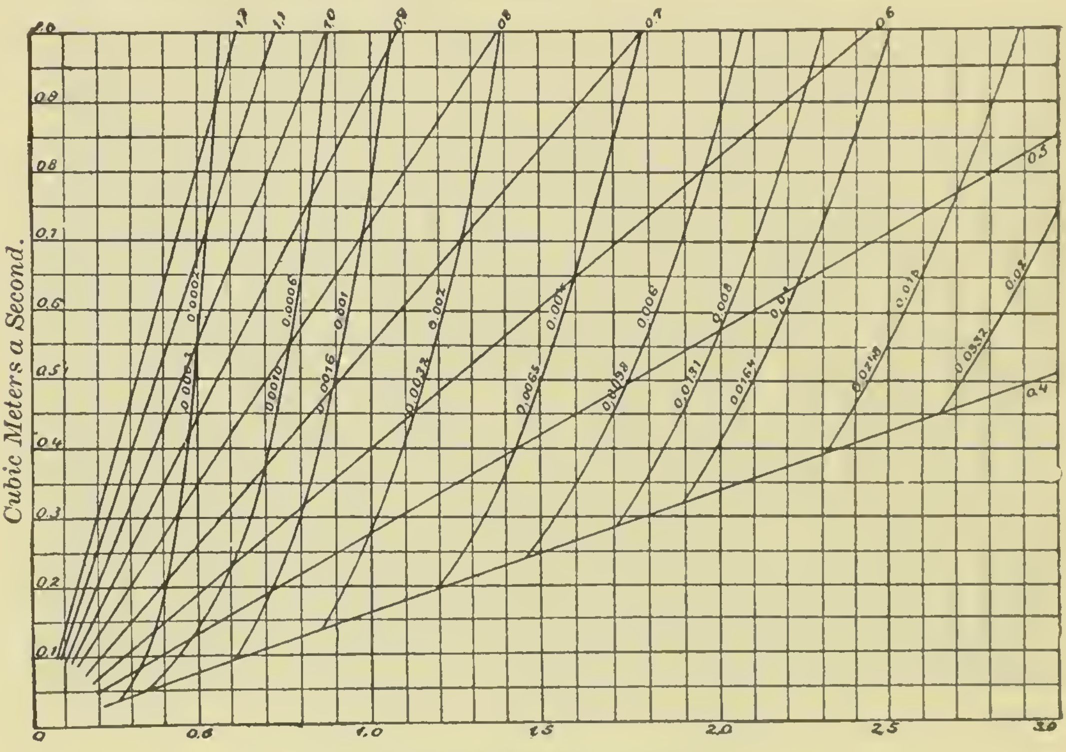


FIG. 26.—GENERAL DIAGRAM FOR EGG SECTIONS.

b. SCHÜCK and others. For circular and egg sections; based on KUTTER, but with the highest class of smoothness.

c. HOBRECHT and others. For circular and other sections; based on EYTELWEIN and lacking values of v.

d. FRANK. For circular and egg sections. These diagrams are formed by two sets of lines intersecting at approximately right angles, and allowing v and y to be read off with great ease, but give only factors, *i. e.*, $Q\frac{4r^2}{f}$ and r, of Q and d.

Fig. 27 furnishes an easy method of calculating the flow at any height of water. The entire height of the section is taken as unity, and the values of y, v and Q for the different heights are laid off as abscissas in such a manner that each of these variables has the value 1, when the sewer is running full. The lines for circular sections are continuous, those for egg-shaped sections are dotted. Hence the process of computation consists either in reading off the values of v and Q from Figs. 25 and 26, and then reducing these

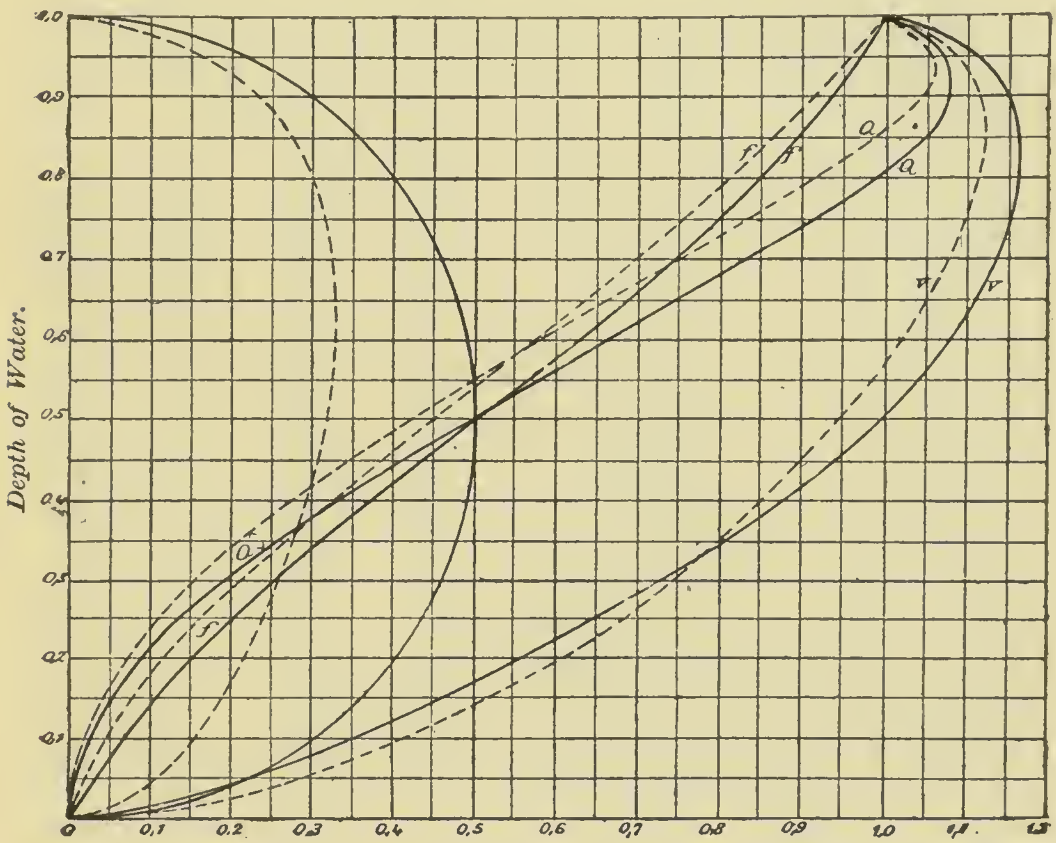


FIG. 27.—DIAGRAM SHOWING RELATIONS BETWEEN QUANTITY OF WATER, Q, VELOCITY, v, AND AREA OF WET SECTION, f, FOR CIRCULAR AND EGG-SHAPED SEWERS FOR ALL DEPTHS OF WATER.

amounts by Fig. 27, or starting with a partly filled section and following a reversed process. The curves given in Fig. 27 are only approximately exact, since they are the mean curves obtained from a number of different assumptions as to the value of b and r. They are correct enough for all ordinary computations, however.

Diagrams of the same nature for a number of other sections have been prepared by FRANK, and the curves have been analytically treated by LUEGER in the *Journal für Gasbeleuchtung und*

Wasserversorgung for 1884. Tables for circular and egg sections, showing the variation in f, r, and v with different depths, were published by KNAUFF in the *Gesundheits-Ingenieur* for 1887.*

The curves in Fig. 27 show many interesting facts. The greatest velocity occurs at a height of 83 per cent. of the whole section with circular, and 85 per cent. with egg sewers; the excess is 16 and 12 per cent. respectively. In circular sections, the velocity at half the total height is the same as when the sewer is full; in egg sewers this occurs at 56 per cent. of the total height. Similar conditions are found on examining the quantities of water flowing at different stages. The quantity in a circular sewer, carried when the wet section has a depth of 81 per cent., in egg sewers at 86 per cent., is the same as with full sewers. The greatest quantity is delivered when the sections are 91 and 94 per cent. full respectively.

These considerations lead to the following rule: Calculate the sewers so that *when running full* they will deliver the amount of water computed according to the methods given in Chapters II. and III. It is not necessary to allow for an empty segment in the upper part of the sewer section. This has been often advocated on the ground of "unforeseen conditions." A glance at Fig. 27 will show, however, that allowance has been made for such unusual bodies of water, for if the quantities to be removed exceed those at the basis of the rule just given, then *the velocity in the sewer will increase and the capacity be augmented* some 6 to 8 per cent. by the depth of the flow sinking to the position of maximum effluent. These considerations show that the above rule will probably lead to the most uniform and economical construction.

* See note, page 282.

CHAPTER VII.

Special Details of Construction.

1. *Manholes*, for examining the interior of a sewer. These are placed from 450 to 700 ft. apart for sewers through which a laborer can pass; in other cases at every change of grade, or never more than 350 ft. apart.

They may be directly over or near the sewer. In the first case

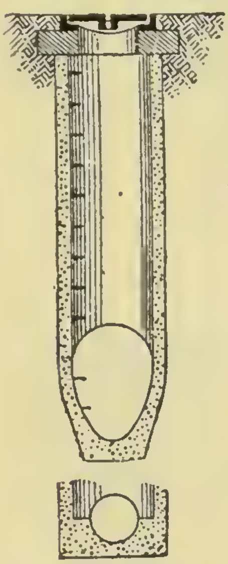


Fig. 28—Heidelberg.

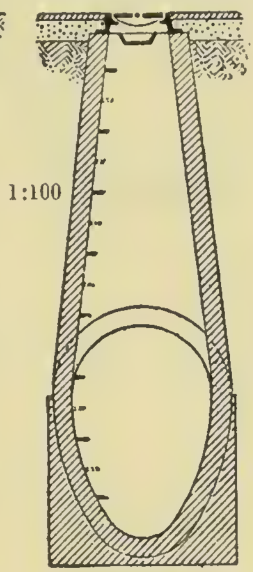


Fig. 29.

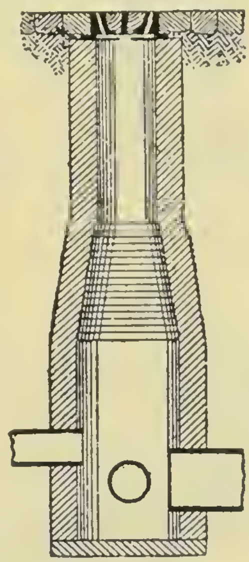


Fig. 30.—Berlin.

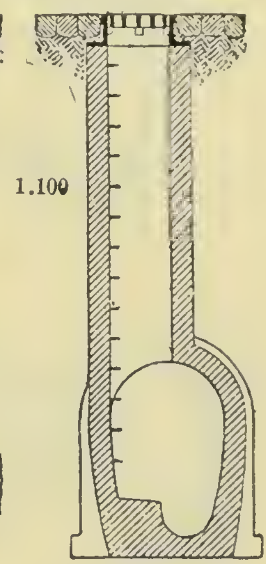


Fig. 31.

Types of Manholes.

they may be over the axis of the sewer, Figs. 28 and 29, over the intersection of several axes, Fig. 30, or slightly eccentric in large sewers, Fig. 31. In the second class, the manholes are designed to give a dry footing near the sewer, Fig. 32, and sometimes, as in Figs. 33 and 34, to allow the entrance to be placed outside of the carriageway. The latter reason, however, is not binding except in narrow streets over which a heavy traffic passes. In Fig. 33 the entrance to the sewer is made easy by an inclination of the manhole, and in Fig. 34 by a flight of steps, but the removal of sand and other sediment is made more difficult by such construction. Two feet is a sufficient diameter for entering a sewer, but it is usual to make the manholes about 3 ft. on account of the in-

creased ease of working. The width of the sewer is often sufficient for the work to be done, Figs. 28 and 29, but an additional space is sometimes obtained by a construction similar to that shown in Fig. 30. The increased space is obtained by making an angle in the masonry, by gradually curving the lines as in Fig. 29,

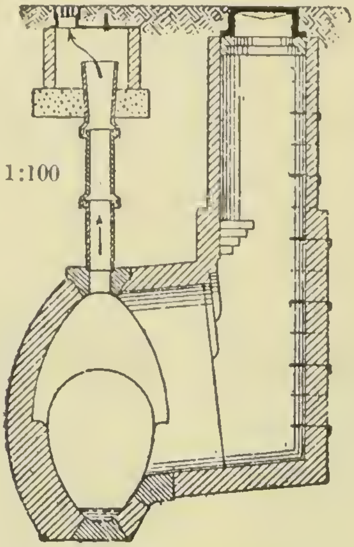


FIG. 32.—FRANKFURT.

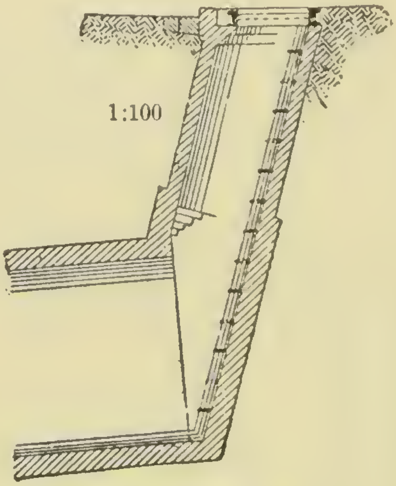


FIG 33.—STUTTGART.

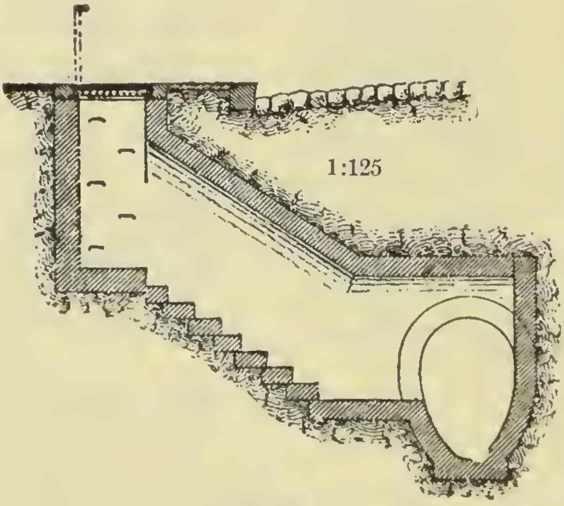


FIG. 34.

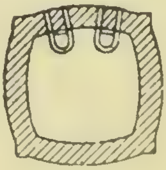


FIG. 35.

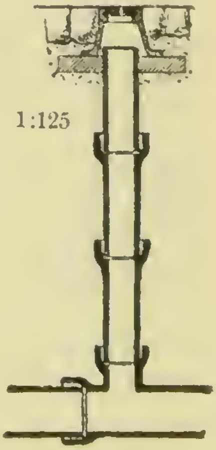


FIG. 36.

or by means of offsets as in Fig. 30. The manholes are usually circular in section, but occasionally elliptical, rectangular, or of the form shown in Fig. 35. The walls are generally 9 or 10 ins. thick, but sometimes only half that amount, where the outer pressure is small; occasionally dressed stone or concrete is employed, Fig. 28. The steps are placed in two vertical rows, Figs. 32 and 35, with a difference in elevation between adjacent steps in the same row of a little over 2 ft. The cast-iron covers rest on crowns of

cast-iron or dressed stone, and are so arranged that wood or cement can be laid on them, thus offering no obstacle to traffic. Where the streets are much frequented two covers may be used, Fig. 34, the lower to be kept closed while workmen are employed below, but provided with suitable holes for ventilation. Or a light frame can be placed about the opening as a guard against accident. The area of such a cover should be as small as possible in order that the paving need not be injured more than is necessary.

In order to economize in the construction of manholes it is

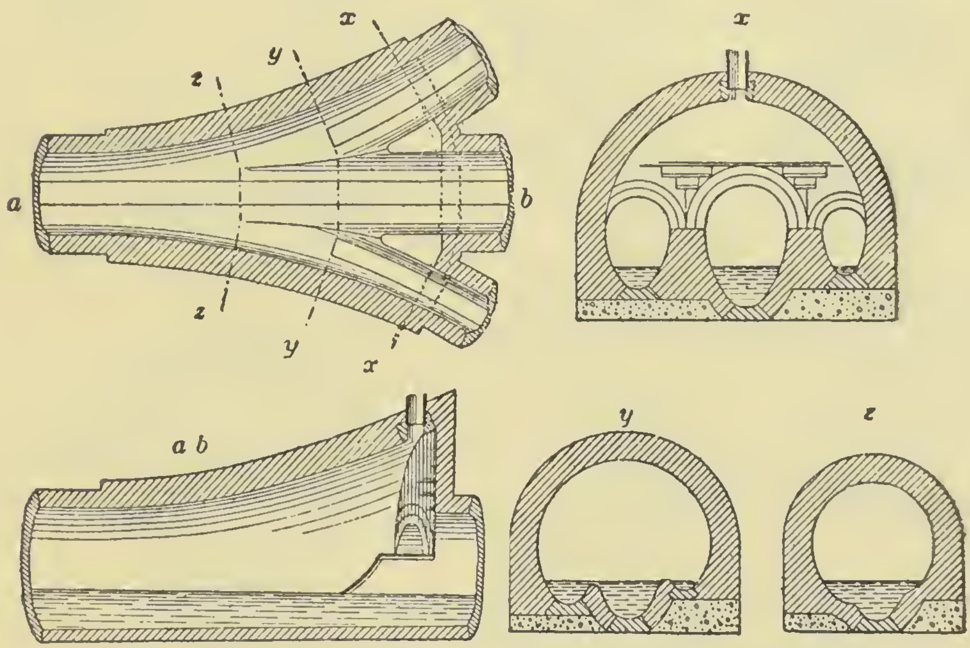


FIG. 37.—INTERSECTION OF BRICK SEWERS, FRANKFURT.

customary to make them alternate with lampholes on long sewers with an uninterrupted axis. A lamphole is made with clay or cement pipes, Fig. 36, from 6 to 10 ins. in diameter, and provided with a suitable cover. A lamp is lowered through this pipe and its light is used in examining the parts of the sewer extending to the nearest manholes. These lampholes are not so much used as formerly.

2. *Junctions of Sewers.*—Sewers should be connected tangentially when possible, in order to obtain a good flow in small sections and avoid too rapid wear of walls in large sections. The radii of the connecting curves should be from 10 to 20 ft. for small* and from 20 to 40 ft. for large sewers. Since the friction is greater in bends than in straight lines, a slight increase of grade

* In all pipe sewers and sewers too small to be entered, the curves should always be entirely within the manholes.

might be given where curvature is found. It is important to have correct entering heights, for sewers emptying into the same large sewer, opposite to each other when the quantities and depths of water are different. If the bottoms of the sewers are on a level, then the smaller will be somewhat choked by the effluent from the larger branch and sediment will be deposited. This condition of affairs is still worse when the main sewer is running full, since both the secondaries will then be partly stopped. If the crowns are placed at the same height, the flow will be perfect

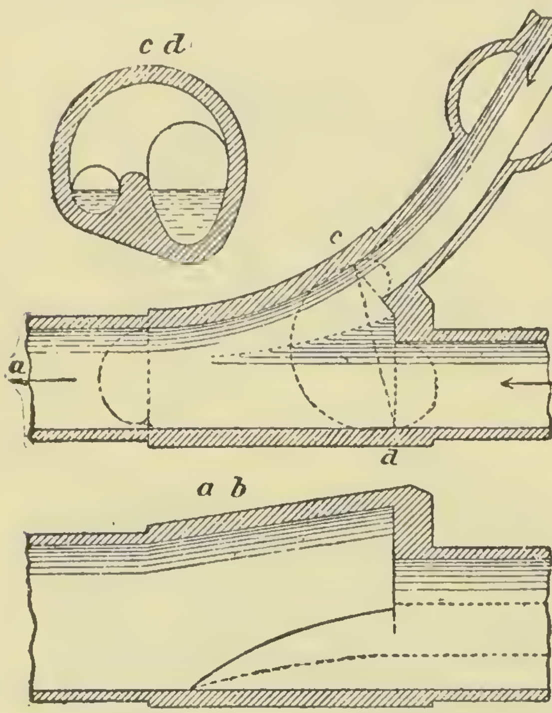


FIG. 38.—INTERSECTION OF CONCRETE SEWERS, HEIDELBERG.

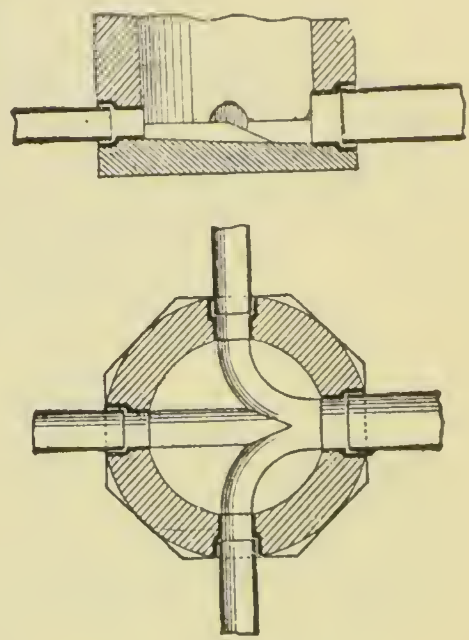


FIG. 39.

during the heavy and protracted storms when the whole system is filled. But in the usual state of affairs the effect of the slope of the small sewer has been lost by raising the position of the entrance to the main section. Hence it is best with flat grades to design the sewerage system to work perfectly when the conditions are those that most often occur; that is, for the average hourly quantity of carrying water during dry weather. When this quantity is flowing the water level in all the sewers meeting at a single point should be the same and equal to that in the effluent sewer from the place. If a uniform grade obtains everywhere then the following statement is approximately true: The wet section will bear the same ratio to the whole section in every

point of the system. Naturally this necessitates a difference in the elevation of the soles, which must be provided for in the designs.

The intersection of three sewers shown in Fig. 37 was designed according to these principles; below are the projecting tongues which divide off the channels, while above is the common

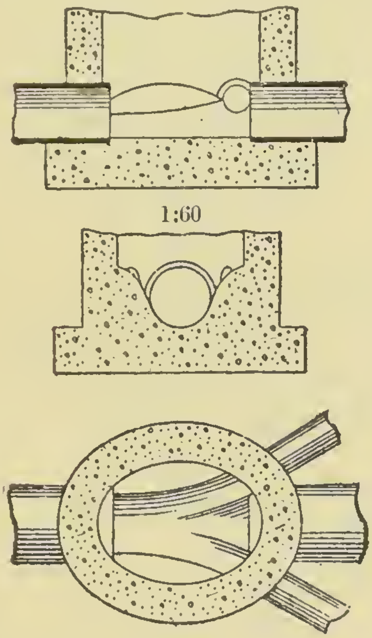


FIG. 40.

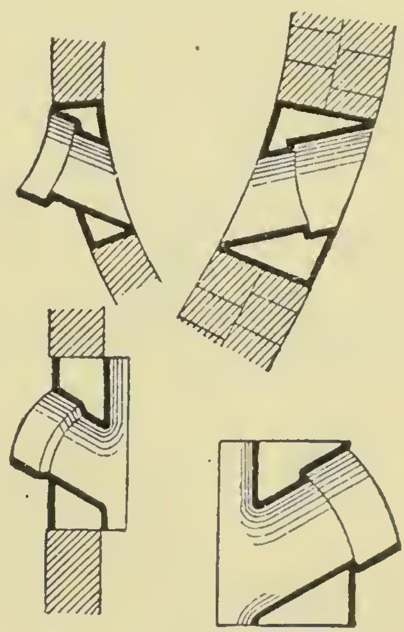


FIG. 41.

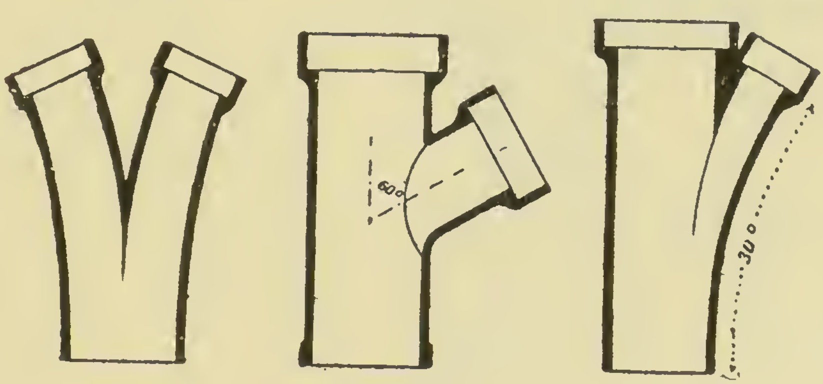


FIG. 42.

trumpet arch. In Fig. 38 a water level was assumed higher than that due to waste water alone; at this level the streams combine regularly without eddies, while at lower stages the smaller stream flows down an incline into the larger, thus avoiding any danger of back water. A manhole is also usually built over the point of intersection. By using sharp curves and a large manhole, Figs. 39 and 40, it will often be possible to have all the

sewers open to inspection. The lower half of the design shown in Fig. 39 is of dressed stone, while Fig. 40 is carried out in concrete. When the drains are half full, the motion of their contents is uniform. In Fig. 30, however, a similar problem has been solved in a very bad manner, and the design naturally results in large quantities of sediment. Such catch-basins were formerly regarded as necessary, but experience shows that in well constructed and flushed sewers they can be omitted, and are even of questionable value on account of the expense of cleaning them. In Berlin it is customary for a laborer to stir up the mud in the manhole during flushing in order to free the mass from organic matter. Only with great differences in level should the branch sewer open into the side of a shaft and allow its contents to plunge down to the bottom, which is usually level with the sole of the main sewer. Even in this case it would be better to curve the branch drain either before or on entering the manhole, and then employ a modification of the arrangement given in Fig. 39. The house drains do not as a rule enter a

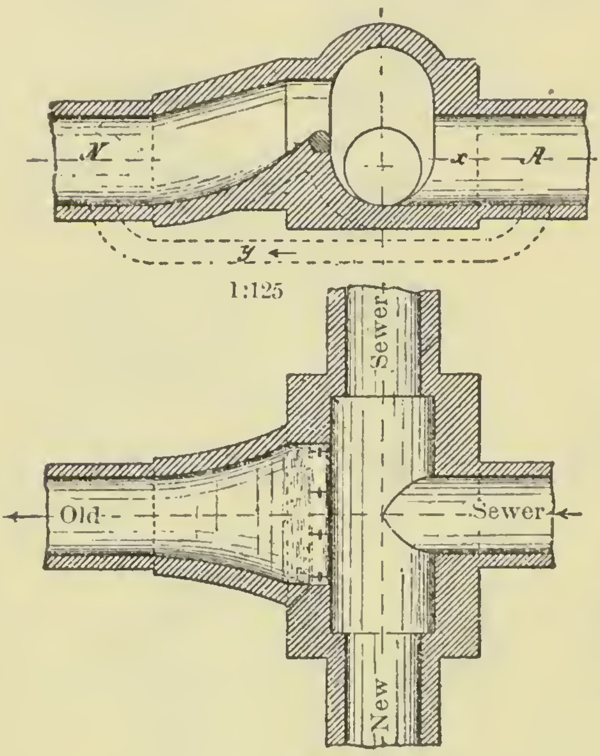


FIG. 43.—RELIEF OUTLET, LONDON.

sewer tangentially but rather at an acute angle. If the sewer is of masonry then either special inlets, Fig. 41, have been built into the walls, or it will be necessary to insert a short section of pipe through a hole broken for the purpose. Wherever it is necessary to avoid steep grades in the drain, the lowest point of its entrance into the main sewer should be at the same height as the water level in the latter during dry weather, in order to prevent back water during the normal condition of the system. When, however, the grade is steep, as is usually the case in house connections, then the outlet is ordinarily placed at the springing line of the arch, or even in the arch itself. In this way there is lit-

the danger of any choking of the drains even during prolonged storms.

In concrete sewers, side inlets are formed during construction. In pipe sewers, special lengths, called branches, are provided for making proper connections, Fig. 42. It is better to have the crowns of the separate inlets at the same level rather than the respective axes, as in this way a more perfect ventilation and flow of water can be obtained.

It is necessary to make some reference to the designs of LIERNUR, who proposes to arrange the outlets to act as "injectors"

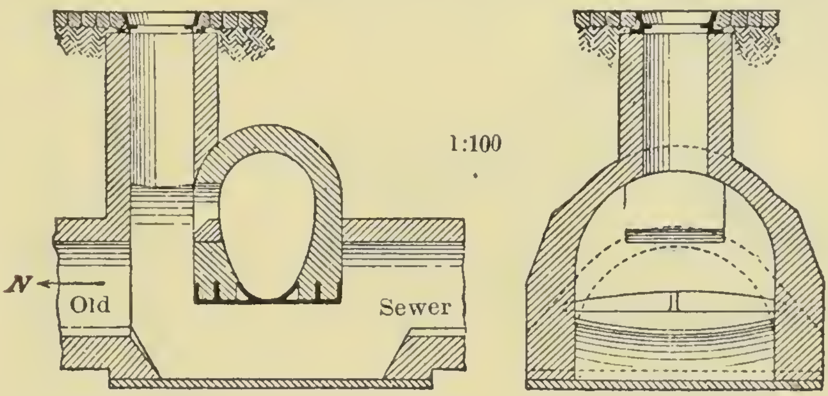


FIG. 41.—INTERSECTION OF SEWERS, BERLIN.

in order to increase the velocity of the current and permit the use of horizontal sewers. These designs are founded on incorrect assumptions, and offer no advantages over the usual forms.

Relief Outlets.—It is first necessary to fix the degree of dilution of the domestic sewage before the overflow through the outlet begins; in other words, to determine the number of parts of rain water which must be added to each part of sewage. The figures for a number of cities are as follows, the numerals denoting the parts of rain water to 1 of sewage:

Chemnitz	5	Kœnigsberg	4.5
Dusseldorf	2.1	Munich	5–7
Emden	7	Vienna	4
Frankfurt	4	Wiesbaden	4
Hamburg	3.4	Berlin	6.4.
Cologne (projected work)	2.2-3.5		

In Freiburg, the outlets are designed to be used as soon as the flow in the sewers is equivalent to 12.36 cu. ft. a person a day. Since the hourly maximum is about 3.53 cu. ft., the ratio of dilution is 3.5.

By means of a suitable coefficient of dilution, n, it is a simple matter to calculate the depth of water when the sewer is running

with the maximum of domestic sewage and n times that amount of rain water, which water level is that corresponding to the sill of the outlet. If the position of each outlet of a system is calculated in this manner, the whole system will begin to discharge through the relief outlets at about the same time. Changes must be made in the designs as soon as the local conditions become different. If a ward or district becomes more densely inhabited, or the quantity of domestic sewage becomes greater in any other way, then the sills of the relief outlets must be raised if the co-

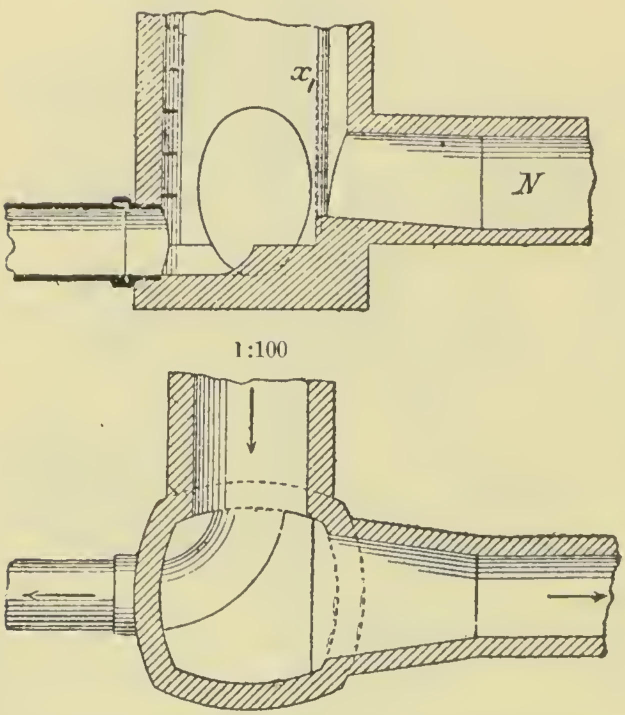


FIG. 45.—RELIEF OUTLET WITH FLASHBOARDS.

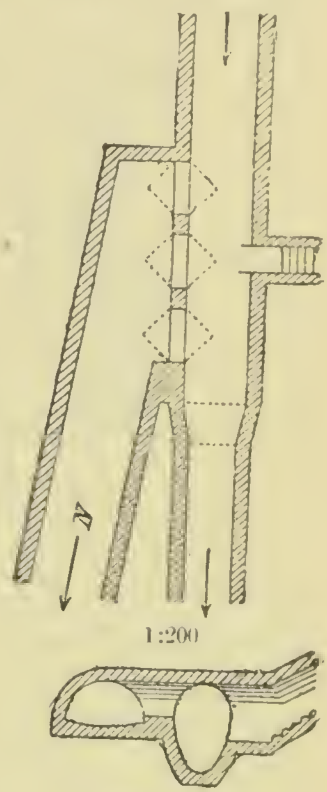


FIG. 46.

efficient of dilution is to be retained. Hence it may be advisable to close the outlets with flashboards, and thus always have a means of regulating the amount of the outfall.

The outlet should be quite broad in order that the water may escape as rapidly as possible. On this account stone sills are let into the side of the sewer, as shown in Figs. 43 and 44. In Fig. 46 a row of arched openings is represented, which together give a quite broad area. With smaller sewers it is best to build a shaft, Fig. 45, and place a broad flashboard before the outlet. It is not always customary to make the sewer sections below the relief outlets smaller than above; the usual practice is to keep the water

level and sole of the sewer on continuous grades, if possible. Figs. 45 and 46 represent such cases. It is necessary to make the outlets accessible, either through the sewer itself, Figs. 43 and 47, through a manhole over the sill, Fig. 44, by building the sill of the outlet into the manhole, Fig. 45, or by means of a flight of steps at one side.

The designs for the relief sewers fall under one of four heads according to the available difference in level between the sill of the outlet and the sole of the outlet sewer proper.

a. When this difference may be made as great as is desirable. The outlet shown in Fig. 44 was built in an old intersecting sewer. In Fig. 43 the soles of all the sewers are on the same level; in this case, the old sewer is either connected with the new and acts as a receiving basin, or, if this cannot be allowed, it is cut off as indicated by the dotted line *x*, and a pipe connection, *y*, formed for the purpose of carrying off any water that may enter *A*. The arrangement shown in Fig. 44 calls for a cast-iron supporting plate for the base of the upper sewer and a depression of the lower sewer. When the conditions are more favorable the construction is much more simple.

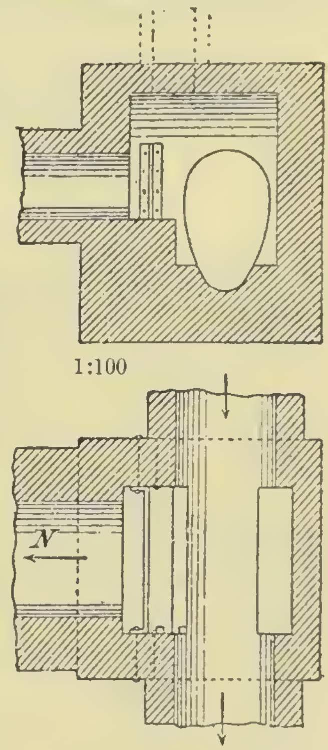


FIG. 47.—BERLIN.

b. When the difference in elevation is very slight. In this case the sole of the outfall is on a level with or but slightly below the sill of the outlet, and the grade is very gentle, necessitating a wide section, Figs. 45–47.

c. When a negative difference is possible, viz.: when the outlet is occasionally under water. In this case the sill of the outlet corresponds to low or mean water in the outfall into which it empties, and the arrangement shown in Figs. 45–47 is retained. It is possible to raise the practical height of the sill by means of flashboards, and in this way prevent the water in the outfall from backing into the sewer, Fig. 45. During such conditions the operation of the outlet is either restricted or entirely stopped. This naturally calls for a greater capacity in the sewerage system. In Berlin, the flashboards are usually constructed of iron, 4 ins. wide and ¼ in.

thick, and are held in position by iron guides, Fig. 47. In this way variations in the water level can easily be provided for and the best results obtained from the outlets.

d. When an outlet can be made the whole depth of the sewer. The moment at which discharge happens and the amount of dilution the sewage is to receive, depend either on the judgment of the laborers in charge, or are more often fixed by rules. This plan requires an additional expense for labor but affords a more rapid emptying of the system. In Budapest, a subterranean outlet is automatically opened by means of a float when a certain level has been reached.

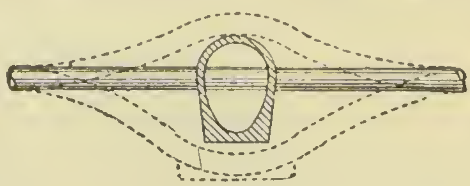


FIG. 48.

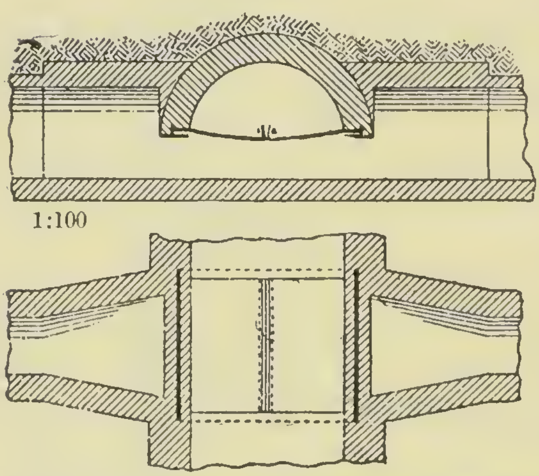


FIG. 49.—INTERSECTION OF SEWERS, BERLIN.

Pumps. — The maximum work for the pumping engines occurs when there are no relief outlets in the system or those which exist are stopped. The pumps must then be able to dispose of the greatest probable rainfall in order to prevent the sewers becoming choked. Since the sewage flowing during the longest storms is not usually pumped to filtration beds, but is run direct into the river, lake or other recipient, the lift of the pumps is generally diminished and the extra work due to increased quantities is partly counterbalanced in this way.

Another case occurs where a relief outlet is built in the main sewer between the pumping station and the city; when this construction is employed the coefficient of dilution varies from 4 to 7.

The most favorable arrangement, as regards the pumping plant, occurs when there are a number of relief outlets in the city. At the moment that these begin to discharge the coefficient of dilution in the whole system will be n, as already explained. After the outlets have been discharging for some time, the domestic sewage will be considerably modified before reaching the pumps, part of the impurities having been washed away. Hence the pumps are not necessarily required to dispose of a quantity of

rain water equal to n times the domestic sewage of the whole city; but it is usually sufficient to employ a smaller coefficient without decreasing the degree of dilution of the sewage entering the pumps. If the numbers marked with an asterisk in Table III. are divided by the corresponding numbers in Table I., the following values of m can be obtained:

Berlin, 1.0; Breslau, 2.8; Danzig, 0.9.

A comparison of the quantities of water passing through the London pumping stations with the domestic sewage of that city, shows that in the North side, m is 1.4 and in the South side, 0.5. The greatest duty of the engines is therefore $1 + m$ times the hour maximum of waste water. With numerous relief outlets, this factor is probably about 2, especially in large cities.

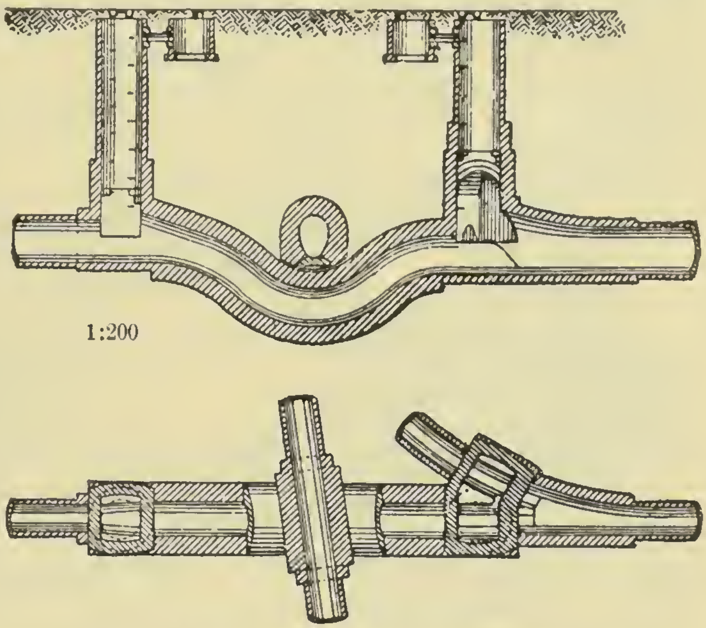


FIG. 50.—SEWER INTERSECTIONS AT FRANKFURT.

The numbers given in the preceding tables are based, to some extent, on projected works. The working of the pumps, according to the best modern practice, can be understood by examining the Berlin plant. In the inner districts of the city, where the population averages 88,400 to the square mile, the city water-works furnish 2.26 cu. ft. a day per capita, which may also be taken as the amount entering the sewers, hence the waste water per second from each square mile will be

$$\frac{88,400 \times 2.26}{18 \times 3,600} = 3.08 \text{ cu. ft.}$$

The pumps will dispose of 10.73 cu. ft. per second from each square mile, hence the coefficient m is $(10.73-3.08) \div 3.08 = 2.5$ These results suppose that the domestic sewage passes into the system during 18 hours of the day alone.

If the number of inhabitants and amount of domestic sewage

increase to the limiting values assumed in designing the system, which correspond to 12.02 cu. ft. of waste water a second a square mile, then the maximum capacity of the present stations can be increased to 24.41 cu. ft., making the ultimate value of m sink to

$$\frac{24.41 - 12.02}{12.02} = 1.$$

When the sewerage system is running full, its capacity is 191 cu. ft. per second per square mile; hence under present conditions 3.08 cu. ft. of waste water will be mixed with 187.92 cu. ft. of rain water, making the coefficient of dilution (on the supposition that all the relief outlets are closed) about 61; under the conditions assumed in the designs, 12.02 cu. ft. of waste will be combined with 178 cu. ft. of rain water, giving a coefficient of 15. The

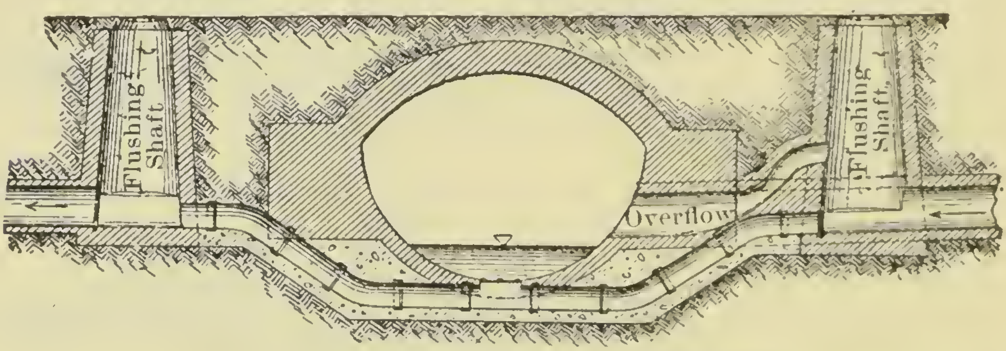


FIG. 51.—INVERTED SIPHON AT WIESBADEN.

actual relation with all the outlets open, existing between the sewage passing through the pumps and that escaping by the outlets, is

$$10.74 : (191 - 10.74) = 1:17$$

The minimum of duty may sink to 0 during the nights of a dry season, but such an occurrence would probably be rare because the lines to the different parts of the city are not of the same length and they would not deliver their smallest quantities of water to the pumping station at the same time. On account of the variable duty of the engines, it is usual to have several pumps of different capacities, in order to run in the most economical manner. The boilers should be designed to make steam rapidly and where the quantity of sewage to be handled fluctuates rapidly, it is desirable to have gas engines in reserve. In such cases it is also desirable to have receiving tanks into which the sewage may be turned, as explained in Chapter I.

The lift of the pumps is also apt to be variable, as when they

discharge into rivers with a fluctuating water level, and it is necessary at times to have appliances at hand for equalizing the duty. But it is to be noticed that the maximum lift and maximum quantity of water will rarely occur at the same time, and it is the general practice in such cases to calculate the dimensions of the plant under the assumption that the maximum quantity of water occurs simultaneously with the mean value of the different lifts throughout the year.

It is bad management to pump nearly dry a system that is near a large body of water, for in this case the sewers are apt to

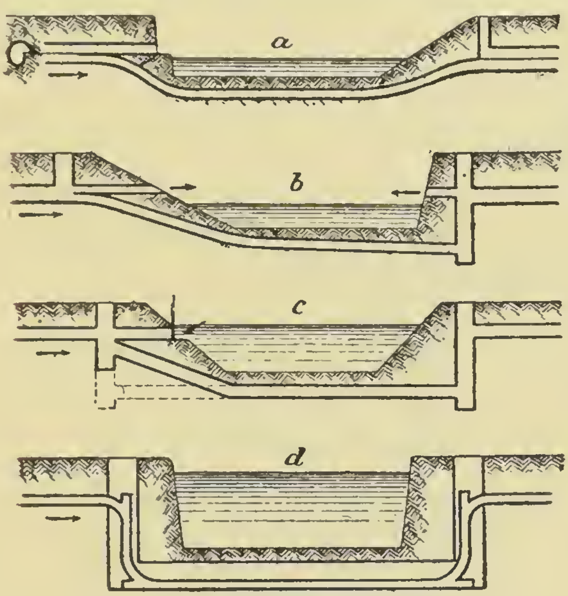


FIG 52.—INVERTED SIPHONS.

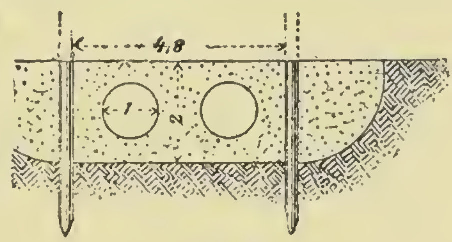


FIG. 53.

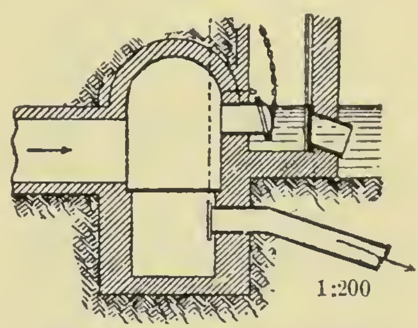


FIG. 54.—OUTLET AT DANZIG.

be injured by the pressure of the ground water. The difference in elevation between the level in the river or other body of water, and that in the sewers should not exceed from 12 to 16 ft.

Intersections with Pipes and Drains.—If a sewer crosses the line of a gas or water pipe, the latter may be bent over, or below, or pass through the former, Fig. 48. The last method is only possible when a diminution of section appears allowable. When the other plans must be adopted, the choice must be governed by the local conditions of foundation, frost and elevation. In every case it is best to change the direction of pipes under pressure so that they will be subject to least danger of breakage.

When a sewer is crossed by another, an old sewer not yet entirely given up, or the outfall from an outlet, or the trunk sewer of another district, the higher sewer is supported on a cast-iron

bed plate, and the lower is widened or deepened to compensate for the change, Fig. 49. The latter construction passes gradually into an inverted siphon, Figs. 50 and 51. If the lower sewer is very large, then the upper is often carried through it by an iron pipe, as shown in Fig. 48.

When it is necessary to cross a water course this is accomplished by a siphon, upright or inverted. The latter form is more liable to be closed by sediment, but it offers a number of advantages. Four cases occur, shown in Fig. 52.

a. A horizontal invert, with as easy connecting curves as possible; used when the difference in elevation between the ends of the siphon is considerable.

b. An inclined invert, with a manhole and catch basin at the outlet.

c. An inclined invert, straight or broken, according to the configuration of the river bed, with catch basins at both ends.

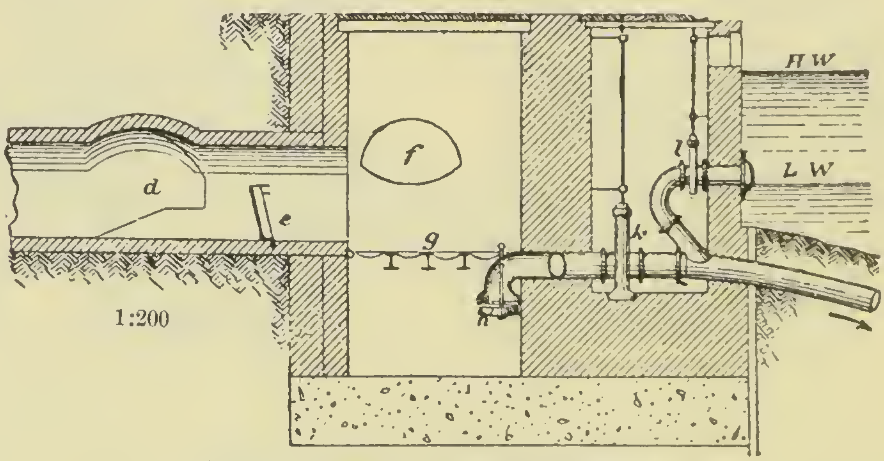


FIG. 55.—INLET TO INVERTED SIPHON.

d. The whole siphon carried in a larger tunnel for use in making repairs and in cleaning.

Although slight differences in elevation and good ground will sometimes allow the inverted siphon to be constructed of masonry, they are usually constructed of iron pipes, the section being considerably smaller than that of the sewers they connect, in order to gain velocity, and hence scouring power, in the water passing through them.

For short lengths and good foundations, cast-iron is a good material for the siphons. In other cases it is best to use pipes of riveted iron from 0.4 to 0.8 ins. in thickness. The pipes are usually connected together and then simultaneously lowered from

a stationary or floating platform into a ditch previously dredged out to receive them. The line is usually protected by sheet piling, concrete, or both. Fig. 53 is a cross section of the double invert under the Seine River near the Alma bridge at Paris. These pipes carry all the sewage of the districts south of the river to the northern districts, delivering on an average 31.2 cu. ft. per second per square mile, with a velocity of 7.2 ft.

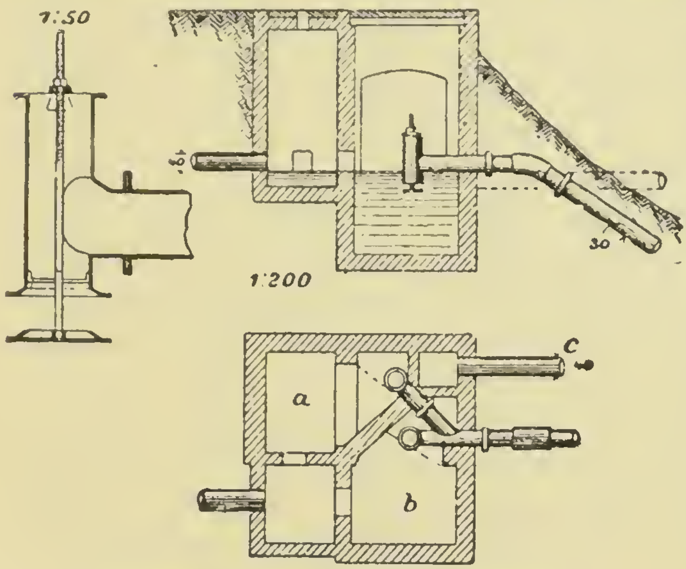


FIG. 56.—INVERTED SIPHON, BRESLAU.

The grade of an inverted siphon, *i. e.*, the difference in elevation between the two ends, is usually taken somewhat greater than elsewhere in the system in order to increase the velocity of the current. Manholes, screens to stop all large bodies, relief outlets, Fig. 52 *b*, especially at the lower end; arrangements for flushing with sewage or fresh water, all are useful in keeping the siphon clean. All these devices are united in the arrangement shown in Fig. 54. The $27\frac{1}{2}$-in. siphon is formed of riveted plates, the catch basin is covered with a screen, and there is a flushing valve at the beginning of the invert proper. The relief outlet is so arranged that water may be taken from the river through it for flushing purposes, if it is so desired.

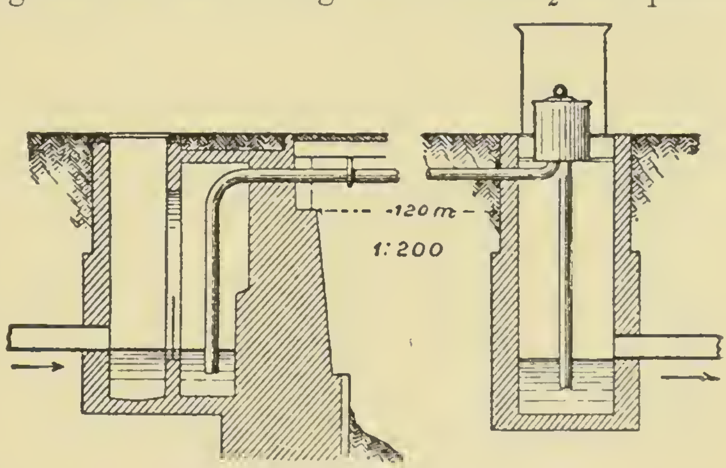


FIG. 57.—SIPHON IN BRESLAU.

A still more complete arrangement, shown in Fig. 55, was designed by WIEBE. In this figure, *d* is placed at the fork of the

sewer, where it divides into two branches, for there are two separate pits into which the sewage is alternately admitted. This duplication of the plant enables the system to be easily and rapidly cleaned. At *e* is a gate for use in flushing, at *f* is a relief outlet, at *g* is a removable screen, *h* is a flap for closing the siphon during cleaning, *k* is a valve to prevent sewage from entering the siphon when it is desired to clean it with water admitted by the valve *l*. A similar arrangement was designed for Breslau, Fig. 56. Here there are two chambers, *a* and *b*, into which the sewage is alternately pumped. Each chamber is quite deep, in order to check the current and precipitate the greater part of the solids. At *c* is a pipe which serves both as a relief and an intake from the river when the siphon is to be flushed.

It is sometimes possible to use a regular siphon in place of these inverts. Fig. 57 represents such a siphon in use in Breslau. The sewage flows into a catch basin, through a screen and is then carried through a 6-in. pipe attached to a bridge to a second catch basin. There is a difference in elevation of 10 ins. between the ends of the siphon. An air lock is placed over the second catch basin, as shown in the cut, and the air thus collected is automatically released whenever the level of the water in the lock sinks to a certain point. The pipes are covered with a thick wrapping to guard against the frost. The upright siphon is much less liable to be stopped by sediment than the inverted type, and is less expensive, both in first cost and subsequent repairs.

CHAPTER VIII.

Catch Basins.

1. *Street Catch Basins.*—The inlets of these may be entirely open and cut in the curb stone, as in Fig. 65, or partly closed, either by a stone cap as in Fig. 58, or by a cast-iron hood as in Figs. 62 and 67. Their height is from 4 to 6 ins. and the width varies from 1 to 4 ft. When the inlet is horizontal, the old custom was to have a stone slab for a cover, but the present practice is to use an iron casting, either funnel-shaped or flat, Figs. 63–69. These castings are commonly from 1 to 2 ft. long. Occasionally they are formed of wrought iron bars 0.8 to 1 in. thick, 2 to 4 ins. deep, and spaced so that the openings are from 0.8 to 1.6 ins. wide. The covers are either hinged, as in Figs. 60 and 61, or loose in their beds, as in Figs. 67–69. Of the two positions, the upright is to be preferred as out of the way of wheels and less liable to be stopped, but has been found to allow a greater amount of solids to enter the sewers. This can be partly remedied by using a coarse screen as is done in Brussels, Fig. 62. In the markets of Paris iron baskets are hung below the inlets in order to catch the refuse.

In some of the older sewer systems all the street water and refuse is carried into the sewers directly from the inlets, Figs. 58–60. Such a plan is uneconomical, as the cost of removing the deposits is then quite high. In a good sewerage system deposits should be formed but rarely. Even if heavy rains carry a large amount of fine sand into the sewers, the unusual quantity of water will be sufficient to carry off all but the largest solids, which should, indeed, be prevented from entering the system. This is done by silt pits, Figs. 61, 63–69. It is sometimes desirable to incline the silt pits in narrow streets toward the center of the roadway and lead away the sewage by side sewers, as is done in Munich.

The dimensions of a catch basin depend upon the area of hard surface which it drains, usually from 480 to 960 sq. yds.; additions to this area from lawns and gardens may increase the

surface to 1,200 sq. yds. The cross section of the shaft is usually square or round measuring from 1.3 to 2.6 ft. on a side or in diameter. A German empirical rule is to allow as many millimeters diameter as there are square meters of drainage surface. Those basins which receive the water and refuse of steep streets should have much larger dimensions.

The water level in these street catch basins should be from 2 to 3 ft. lower than the street surface, as a protection against frost. The total depth of the basin should be from 6 to 8 ft., as when a less depth is chosen there is danger of freezing. Masonry has given way to cement, clay, or iron pipes as a material for this work. These pipes are usually 2–3, 1–1½ and 0.8–1 in. in thickness for the different kinds mentioned. Cast-iron is least adapted on ac-

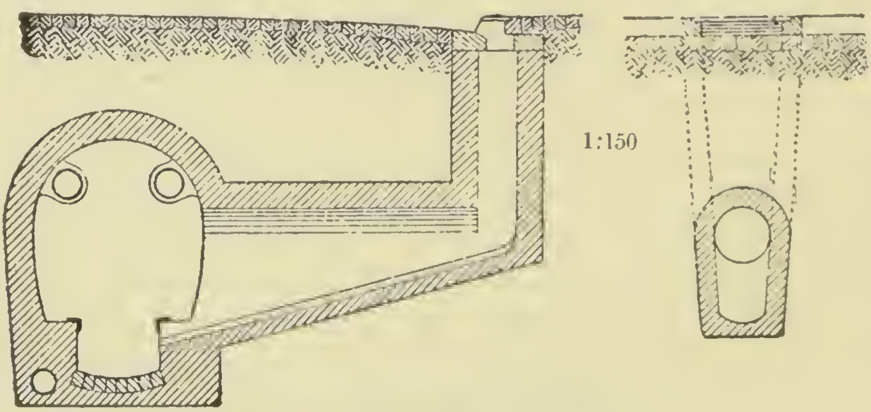


Fig. 58.—Street Inlet, Paris.

count of its liability to rust. The shaft usually consists of two or three pieces, and carries the inlet at its upper end, as shown in Fig. 69, although this is occasionally supported, as shown in Fig. 67, in order to make future adjustments to grade as easy as possible.

Formerly no provision was made against the escape of sewer air, Figs. 58 and 59. Now it is necessary to use more care in building the catch basins near sidewalks. In Hamburg a small flap valve, shown in Fig. 60, has been adopted. This is opened by the escaping water and is very simple in all respects, but by no means tight in dry weather.

The use of valves in any part of the inlet is of little value, as has been shown in the older sewers at Munich and Linz. A better and more simple connection is made by a common water trap, 4 to 8 ins. deep. This may be formed by a tongue, as shown in Figs. 63 and 64, by an inverted outlet, as in Figs. 65, 66, 68 and 69, or

by some special arrangement similar to that shown in Fig. 67. The outlet shown in Fig. 63 is cleaned by folding back the hinged flap. Those shown in Figs. 65 and 66 are cleaned by simply removing the short curved outlet, while the other forms illustrated can only be cleaned by flushing. At *x*, Fig. 67, is shown a water-trap, which offers the great advantage over the form represented in place in the cut, of being easily cleaned without breaking into the pipe, as must be done at *x* in Fig. 68. In all such designs care must be taken to expose as small a surface as possible to the action of rust. In the arrangement shown in Fig. 67, solids

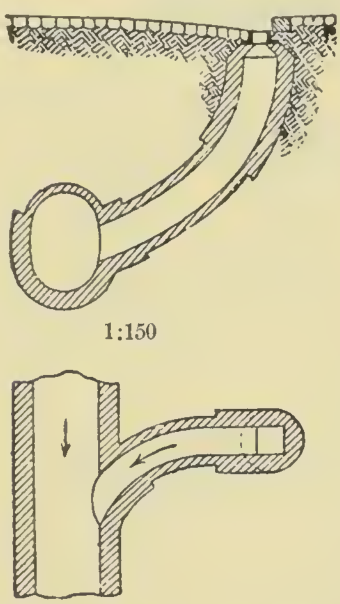


FIG. 59.—STREET INLET, HAMBURG.

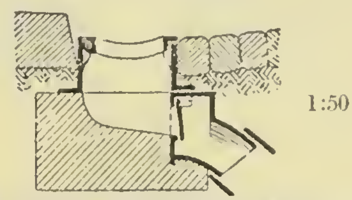


FIG. 60.—STREET INLET, HAMBURG.

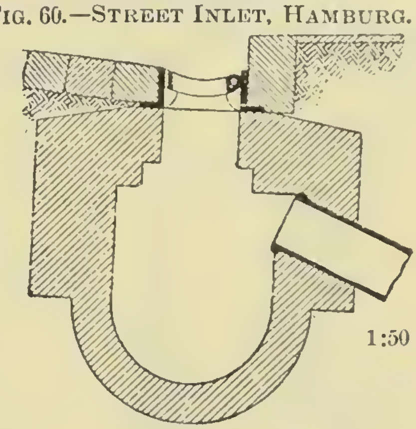


FIG. 61.—STREET INLET, MUNICH.

may be easily caught in the invert, as might also happen in Figs. 63 and 64.

Generally water traps and silt pits are found in the same basin, but this construction is not always adopted. At Brussels a water trap is placed immediately below the inlet, Fig. 62, and the flushing done by means of a connection from the water mains. The opposite of this arrangement is employed in the open suburbs of Munich, where a small catch basin discharges directly into the sewer connection, Fig. 61.

The pipe leading to the sewer is from 5 to 6 ins. in diameter when silt pits are employed, and may be increased to 20 ins. where these are not used. The pipes are best curved or placed at an angle at the intersection with the sewers, except in cases simi-

lar to that shown in Fig. 63, where the sewer lies directly under the catch basin.

The mud is removed from these basins by shovels or by buckets, as shown in Figs. 66, 68 and 69. The diameter of the latter is from 2 to 4 ins. less than that of the shaft in which they are placed and their height is to be determined by the position of the outlet pipe. Holes should be made in the lower part of the bucket in order that the water can drain out as the mud is lifted up to be removed. In order that all the material may en-

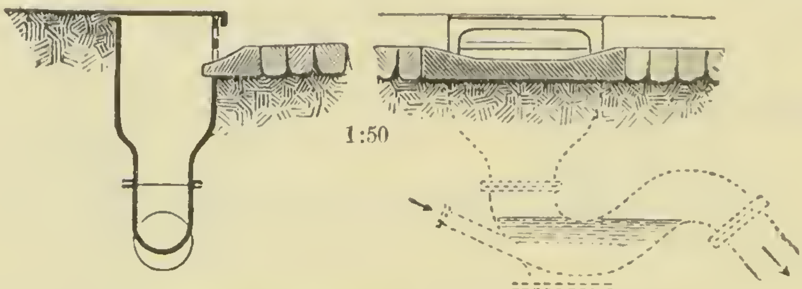


FIG. 62.—STREET INLETS, BRUSSELS.

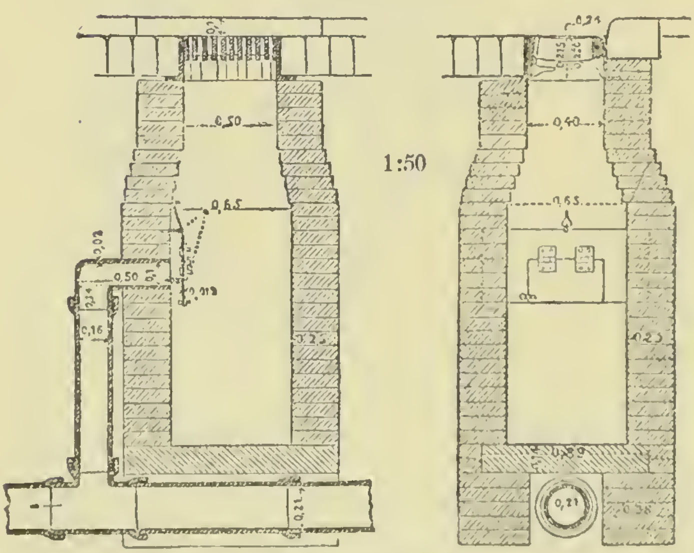


FIG. 63.—STREET INLET, BERLIN.

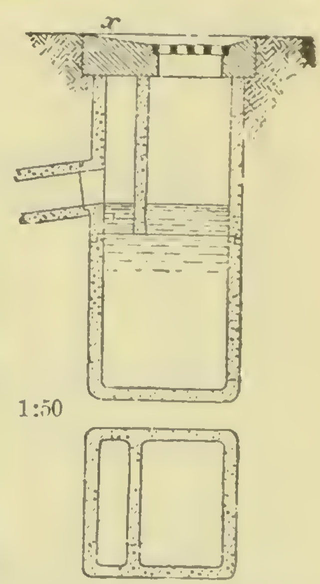


FIG. 64.—STREET INLET, KARLSRUHE.

ter the buckets, it is usual to place small hoppers or funnels under the grating at the inlet, Figs. 67–69. Sand is very apt to settle around the buckets, making their removal somewhat difficult, and it requires considerable labor to empty the mud into the carts which carry it away. In order to diminish this labor, the apparatus shown in Fig. 70 was proposed by GEIGER. The bucket is held in position by an iron ring and receives all the mat-

ter entering the inlet above. Equal atmospheric or hydrostatic pressure above and below the ring is maintained by the small pipe *a b*, so that only the weight of the bucket and its contents has to be lifted. The bottom of the bucket is hinged and held in position by a catch *c*. In replacing the bucket in the shaft, the valve *d* opens when the water level is reached and allows the water to enter until the whole is again in position. Whether the apparatus would work well in muddy places is open to question.

The mud in the basins is always foul, and should be kept covered with water in order that no disagreeable gases may be given off. It is often desirable in prolonged dry weather to occasionally admit water from the service mains. In no case ought the water

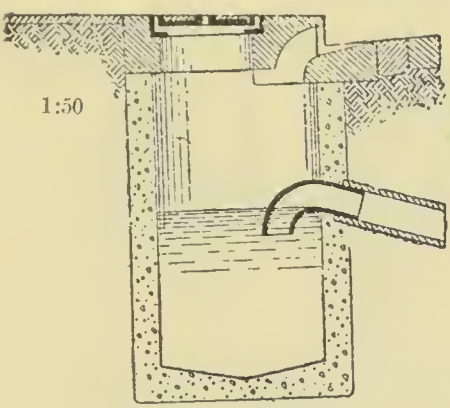


FIG. 65.—STREET INLET AT HEIDELBERG.

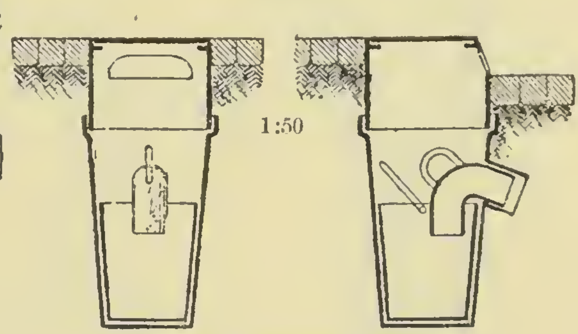


FIG. 66.—STREET INLET AT WIESBADEN.

traps or siphons be placed under the mud buckets, as is done in Budapest, for this construction causes the mud to dry up very quickly.

2. *House Inlets and Connections.*—That all house connections should be separated from the sewers by some kind of water trap is now universally admitted and generally demanded in the specifications for such work. The depth of these traps varies from 2 to 4, or even 6 ins. where there is much grease in the drainings. The means of holding back the impurities are often very scanty. Not only do the usual impurities of street sewage occur in these connections, but also fats, soap and other kitchen and washroom drainings. The fat gradually solidifies in the pipes and forms a tough coating which collects the other matter.

For connections in courts, where sand and leaves form the leading solids swept into the sewers, any of the catch basins

shown in Figs. 63–69 will serve, while in very large courts that represented in Fig. 62 could be employed by omitting the water pipe. They are usually made as small as possible in order to have a good fall to the sewer. The diameter of the basin may be reduced to 10 ins., the depth to $3\frac{1}{4}$ ft., or less, in places not exposed to frost, and the outlet to the sewer need not greatly exceed $3\frac{1}{2}$ ins. Small cast-iron basins of several forms are shown in Figs.

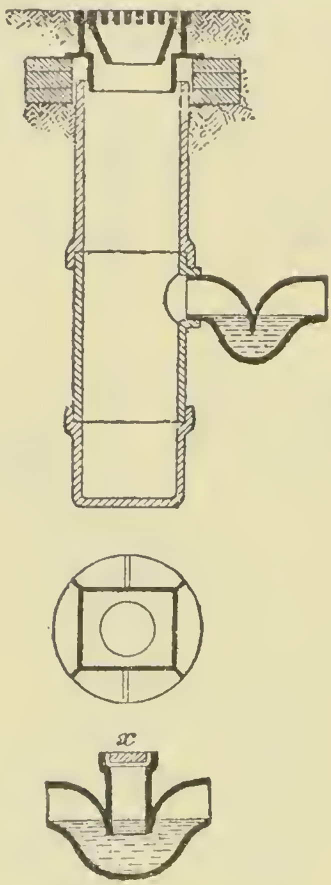


FIG. 67.—FRANKFURT.

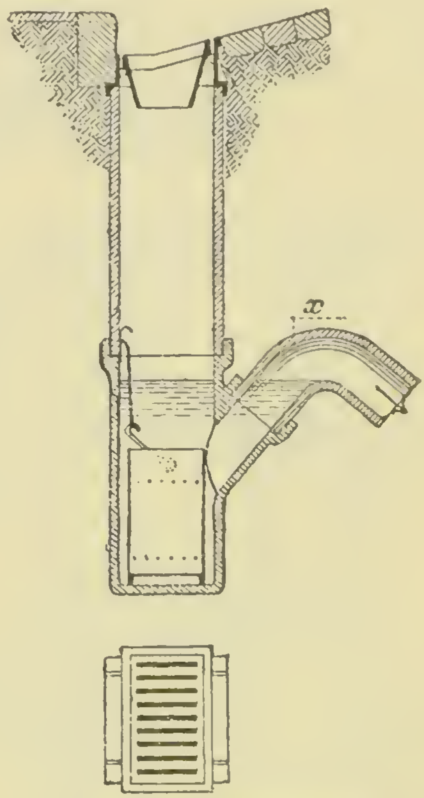


FIG. 68.—KARLSRUHE.

71–74. The dotted lines in Fig. 72 indicate the form to be used in places exposed to frost.

Rain water from roofs, which is apt to carry with it dust, ashes, pieces of slate or tile and similar substances, is usually conducted by suitable drains to a small mud pit at the rear of the house. When this is not possible, special arrangements are made for receiving the water at the front or street side of the house. For this purpose, in Dresden and Cologne a small basin or pit, provided with a cover at the sidewalk level, receives the water from the roofs and discharges it into the sewers through properly fitted outlets. The devices in Figs. 75–77 are much more simple and

as efficacious. In the form shown in Fig. 75 the pipe from the eaves trough is enlarged at the base and fitted with a screen and opening for cleaning, while in Fig. 76 the same arrangement has been adopted but placed underground. The device shown in Fig. 77, and employed in Erfurt and Stuttgart, has the advantage of being well protected from the frost. In Berlin, such arrangements are used only in houses with roofs of earthy material, or in bad condition. Since, however, there is no doubt as to the value of these screens, and their cost is quite low, it seems better to call for their general adoption. Some cities call for merely a

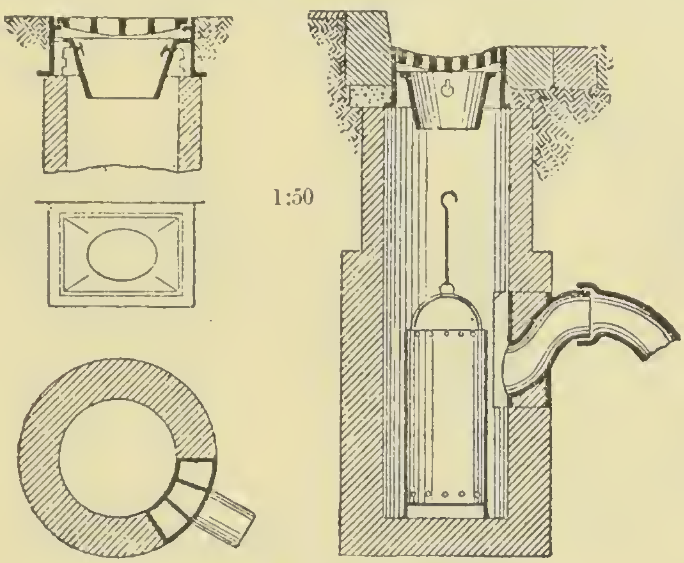


Fig. 69.—Stuttgart.

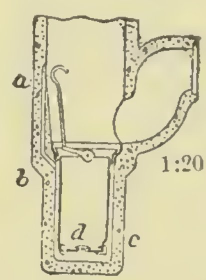


Fig. 70.

knee or bend in the pipe, with an opening for cleaning. In Breslau, the only precaution taken is to place a grating over the top of the eaves pipe, which, however, is stopped more often than would be thought probable, and is difficult to clean. In Wiesbaden, a small basket to keep back the leaves and other objects is placed at the top of the eaves pipe, and a small box or pail at the lower end receives the mud, Fig. 78. Wherever an eaves pipe opens above in the neighborhood of a roof window, and there is danger of sewer air escaping, it is required in Munich to place a water trap at such a point as to prevent this. At Freiburg and Basle these traps are required for every pipe carrying water from roofs.

The house sewage is often screened by passage through a grate and siphon, many cities having expressly ordered each house connection to be provided with a grating and a water trap. For

purifying the drainings from kitchens several forms of grease traps have been used. These cause the fatty matter to be separated by cooling, the grease being retained floating on the water in the trap. An American form, made of stoneware, is shown in Fig. 79. They are usually placed below the sinks, and intercept not only the grease but also all the heavy substances which enter them. In order that the layer of fat on the top of the water may not be agitated too greatly, the drain from the sink should enter from the side and not the top. A pail is some-

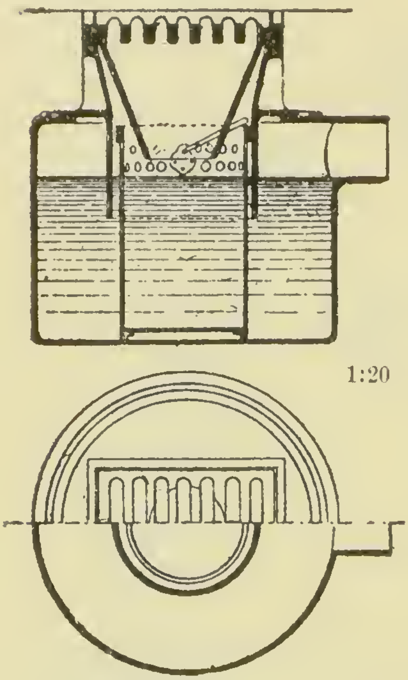


FIG. 71.

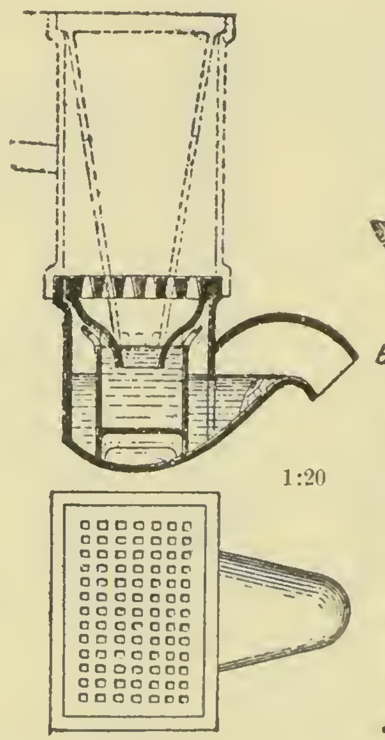


FIG. 72.

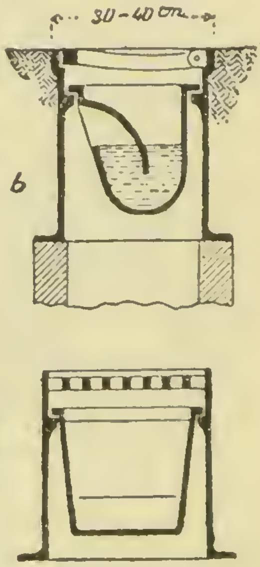


FIG. 73.

times provided for removing the solids, Fig. 80, but it must be provided with tight bearings or all the matter will not be intercepted. If this condition is fulfilled an ordinary catch pit will serve as a fat or grease trap by placing the outlet sufficiently low, Fig. 81. Such an arrangement is often employed for a general catch pit in a court or cellar in case no traps are used in connection with the sinks. It is desirable to have all the pipes nearly vertical, in order that they may remain clean, and to have suitable arrangements for ventilating the drains, thus avoiding any tendency to create a partial vacuum in any part of the connections.

Catch basins with movable partitions or tongues, like those shown in Fig. 63, are not adapted for intercepting floating sub-

stances, for it has been found in practice that during the process of cleaning, a large proportion of the matter floating on the surface of the water is carried into the sewer. Hence no movable tongues or siphons, Fig. 65, are allowed in private basins in Karlsruhe. Where large quantities of water must be handled, it is usual to double the dimensions of the traps or basins, Fig. 82. Where the outflow from manufacturing establishments is large, it should run into precipitating tanks or even receive chemical treatment, before entering the sewers.

The preceding devices for screening house sewage are by no means everywhere used in the same manner, and there are a great

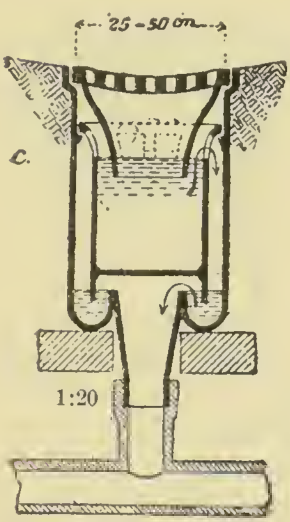


FIG. 74.

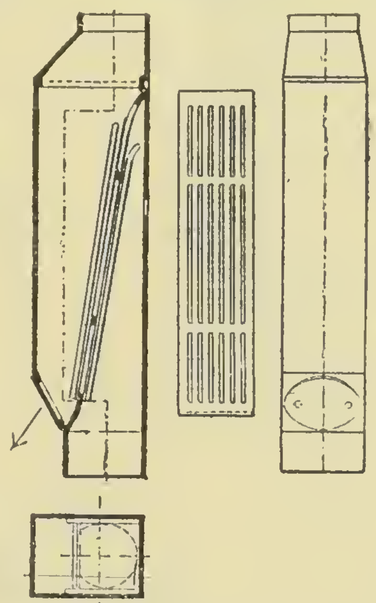


FIG. 75.—GRATINGS IN RAIN PIPES.

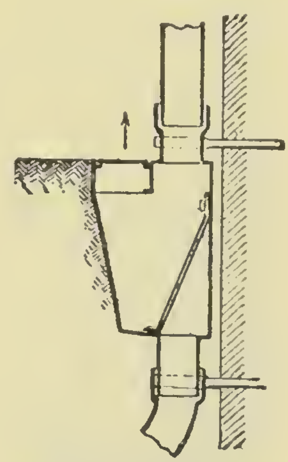


FIG. 76.—RAIN PIPE INLET, KARLSRUHE.

number of regulations concerning water carrying grease and sand. In many cities, as, Hamburg, Frankfurt and Basle, only bends are required under the sinks, and the pipes discharge directly into the sewers, being kept clean by flushing alone. This arrangement has been found to work badly with water containing much fatty matter, and grease traps are often employed although not officially required.

In several other cities, as Berlin, Cologne and Freiburg, kitchens and laundries are generally allowed to discharge directly into the sewers, but where fat and soap are discharged "in unusually large quantities," a grease trap must be connected to the outfall from laundries, restaurants, soap works, abattoirs and

such establishments. In Berlin a very large amount of sand must be taken from the sewers annually, which could be equally well and more cheaply intercepted by house traps, as the greater part of it comes from dwellings where it has been used in cleaning.

Exactly the opposite plan has been adopted in Stuttgart, Karlsruhe, Mainz, Wiesbaden, Gœttingen and Halle. Here all

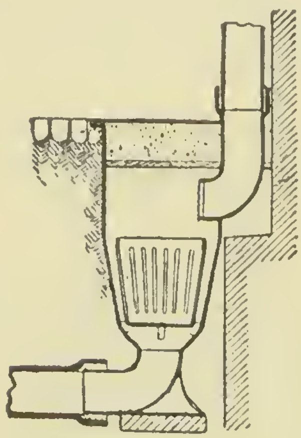


FIG. 77.—RAIN PIPE INLET AT ERFURT.

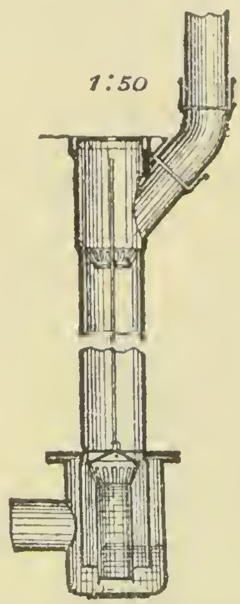


FIG. 78.—WIESBADEN.

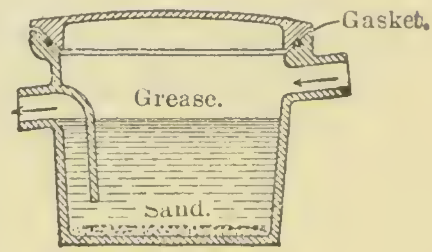


FIG. 79.

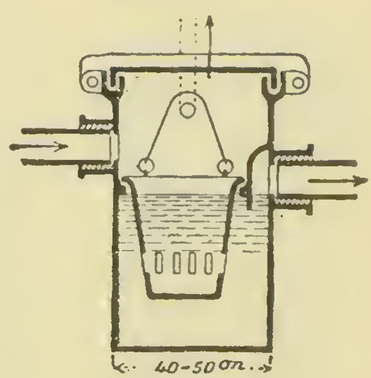


FIG. 80.

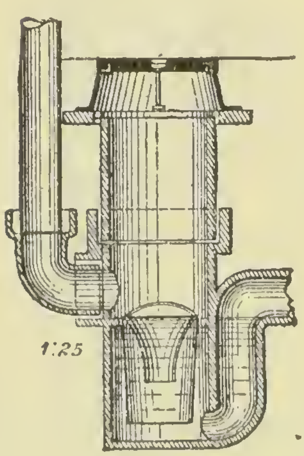


FIG. 81.

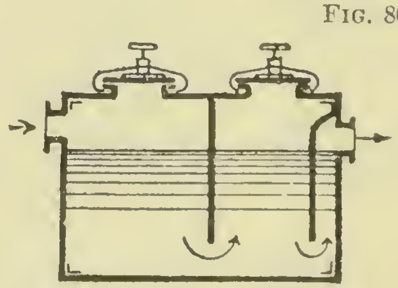


FIG. 82.

water containing fats or sand must pass through traps before leaving the premises. In small houses this may be done in a single pit, to which all the pipes run, and from which the sewer connection is laid. In larger establishments several pits are usually employed, partly on account of ease in laying the pipes and partly to reduce the number of flat grades, and thus diminish the deposits. On the latter account a regulation has been adopted in Weisbaden prohibiting the use of grease traps at a greater distance than 7 ft. from the foot of the house pipe. Since the dis-

charge from courts also requires to be screened before entering the sewers, it will often be found possible to make one pit serve for both the house and court connections, and even for roof water in some cases. Such a combination should not be made without care, or the pit or basin will overflow at times. In Wiesbaden, one pit may only receive the entire discharge from an area less than 54 sq. yds. in extent. In the majority of cities it is not necessary to pass water that is reasonably pure, such as that from baths, through intercepting traps. The rules in use at Karlsruhe read as follows: Rainfall pipes may discharge into the sewer or house drain without a water trap; kitchen pipes must be connected with the sewer by a bend or knee under the inlet, and a catch pit; other discharge pipes to be provided with a siphon or catch pit, or, in cases where unusually large quantities of grease occur, with an easily cleaned grease trap.

The extent to which preliminary purification is to be carried depends entirely on local circumstances. Where the quantity of sand used in the household is small, and the flow of water in the discharge pipes is so rapid as to flush away the sediment that collects, catch pits may be omitted. Since all the domestic sewage must be swept away, it will not do to pass any part through a catch pit, and hence a separate connection ought to be laid to the sewer when the kitchen drainings pass through such a pit. On sanitary grounds, all deposits in the vicinity of a house are to be avoided, and the expense and annoyance attending their removal is considerable. When such are unavoidable, they should be concentrated as much as possible to facilitate removal, and the pipes should be arranged to give the greatest amount of ventilation.

The preceding remarks are based on the supposition that water-closets are used. This is by no means universal, however. In some old cities it is customary to have a dry connection from the privies to the sewers, and even when better sanitary arrangements may be had, to retain such arrangements on economical grounds, or through lack of water for flushing, as in Aachen, Bonn, Linz, Salzburg, and Wurzburg. The evil results of such a practice are many, such as the escape of sewer air into the houses and the formation of offensive deposits in the connecting pipes, which cannot be entirely obviated. The best results are attained by an oft repeated flushing of such connections, by means of hose lines, as in Salzburg, Liverpool, and Danzig.

CHAPTER IX.

Flushing.

For flushing purposes, water may be classified under the following heads:

a. Flowing or standing water at the higher ends of the sewers to be flushed, which can be admitted without previous collection and allowed to drain off from the lower ends of the system into other channels. In Bern, Wurzburg and Innsbruck brooks are used in this manner, while in Freiburg industrial canals are utilized for the purpose.

b. Rivers with a rapid fall, from which water may be taken above the city, and to which it is returned after passing through the sewers, as is done in Breslau, Danzig, Liege, Munich, Reichenhall, Zurich and Strassburg.

c. In places on tidal waters the variation in the sea level is utilized for flushing. In Bremerhafen, for example, water is admitted to the basins during high tide, and allowed to flow from them into the sewers as soon as the water level has fallen sufficiently to cause a scouring action. At Brighton water is admitted at high tide at one end of a sewer running along the shore, and escapes at low tide from the other end. At Emden water is admitted at several points during high tide.

d. Water collected by pumps or pipes at the upper end of the system, either in ditches, reservoirs, or sections of sewers cut off for the purpose. The latter plan is much used where there are several lines of sewers to be flushed and the water for the purpose must be supplied through a single line, as in Danzig and Karlsruhe. Reservoirs fed by brooks are employed in Mainz, Munich, Düsseldorf, Cologne and Wiesbaden. It is necessary to pass the water of the brooks through catch basins in order to remove all the sand before admitting it into the sewers. In Bremen, water is pumped from the Weser River into the moat surrounding the city and then flows into the sewer to be flushed.

e. Rain, spring, and ground water is often collected in reservoirs, usually underground galleries through the walls of which it is admitted. Frankfurt, Stuttgart and Gœttingen have such

reservoirs. In Frankfurt, the gallery is 984 ft. long, 4.6 ft. wide and 5.6 ft. high, and is filled every day except in rainy weather, when it is sometimes filled three times daily.

f. The public water supply is often used. The water is generally admitted to flushing tanks from which it is discharged into the sewers.

g. Water from shops of various kinds is used when it can be had in sufficient quantities. In Dortmund water is taken from the city baths, in Liege from mining establishments, in Linz from a large brewery, and in Pest the water of condensation from large flouring mills is employed.

h. Where free water is lacking, and that from the waterworks is too dear, the sewage itself may be used for flushing. Generally, however, water is also added from the mains to the upper end of the sewer to be cleaned, because there the quantity of sewage is small. In Berlin the addition of water for this purpose averages about 11 cu. ft. a year per capita.

The quiet flow of water in a sewer will only have a cleansing power when large quantities can be used for several hours. This is rarely possible, even where hose connections can be made with hydrants, and in such cases temporary shields are usually placed in the sewers, enough water being thus collected to cause a strong flushing action when the shield is suddenly removed. The sewers are divided into stretches by movable partitions, and each length then separately cleaned. It is customary to begin at the upper end and wash the sand and mud down toward the lower points, although occasionally flushing begins in several points simultaneously, in order to avoid clogging the system in any place. The length of the section that can be flushed with one setting of the partitions varies greatly, being governed by the grade and size of the sections. Care must be taken that the backwater from the lower part of the sewer does not cause inconvenience to the residents along the line, and that the extra pressure does not fracture the pipes or masonry. The partitions employed sometimes occupy the entire cross section of the sewer and sometimes only a portion of it.

When the effect of flushing cannot be well calculated while designing the system, it is best to leave several points in the masonry so arranged that flushing tanks can be placed in position later if found necessary.

The interval between successive flushings varies greatly. Some of the sewers in Hamburg are cleaned in this way every few days; in Berlin every twelve, in Frankfurt and Danzig every three weeks, while in England the interval is from one to three months.

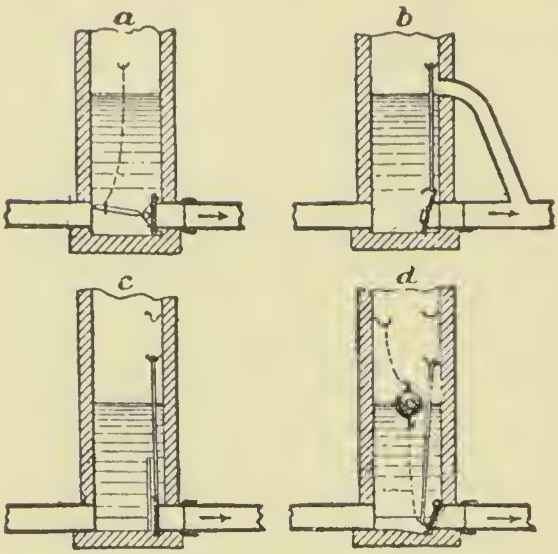


Fig. 83.

The flushing devices may be divided into four classes as follows:

1. *Hand Apparatus.*—In Fig. 83 *a*, the water is kept back by a cover held in place by a small brace. At *b* the cover is held by the hydrostatic pressure alone, while in *c* the cover is also partly supported by a frame in which it slides, and in *d* there is a hinged flap over the outlet. The forms shown at *a* and *b* may be moved from manhole to manhole, but do not adapt themselves to a well-designed base, like that illustrated in Fig. 89. In order to discharge the water it is necessary in all cases for a laborer to enter the manhole and pull the rod or chain connected with the cover. In case he should forget to do this, an overflow pipe is sometimes provided, as at *b*, or a float, as at *d*. The overflow pipe is specially adapted to a manhole in which the inlet pipe has a marked bend, as in Fig. 84, for in such cases there is little backing in the inlet until the overflow begins to act. Where there are no manholes in the proper place for flushing, small pipes can be used for casing in the rods of the covers (Fig. 85). Figs. 86, 87 represent forms of plate covers adapted to larger sewers.

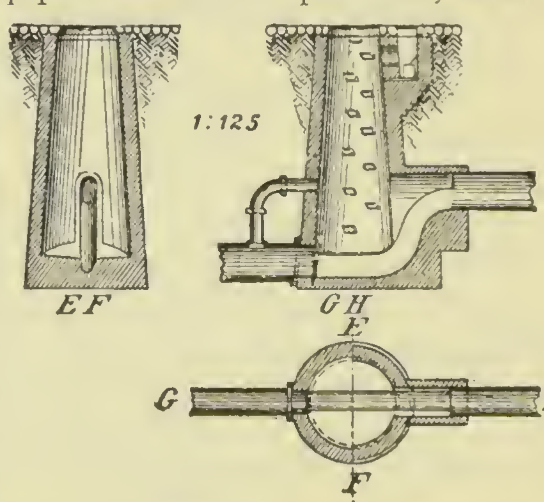


Fig. 84.—Flushing Shaft at Wiesbaden.

2. *Flushing Gates*, revolving on an upright or slightly inclined axis. The two hinges are attached to a cast-iron frame

in Fig. 88, and the gate itself stiffened with braces. While the sewage is held back the gate is braced by an arm which rests against a corner of the masonry. In order to allow the water to escape, this arm must be withdrawn, usually by an attached rod, Fig. 89. The gate must be closed by hand. A more convenient attachment is shown in Fig. 90. The arm is easily thrown from the position shown by solid lines to that indicated by the

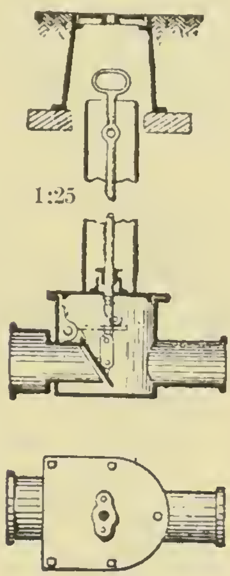


FIG. 85.

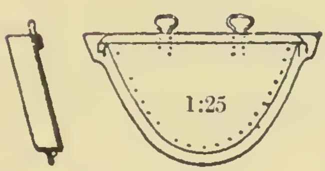


FIG. 86.

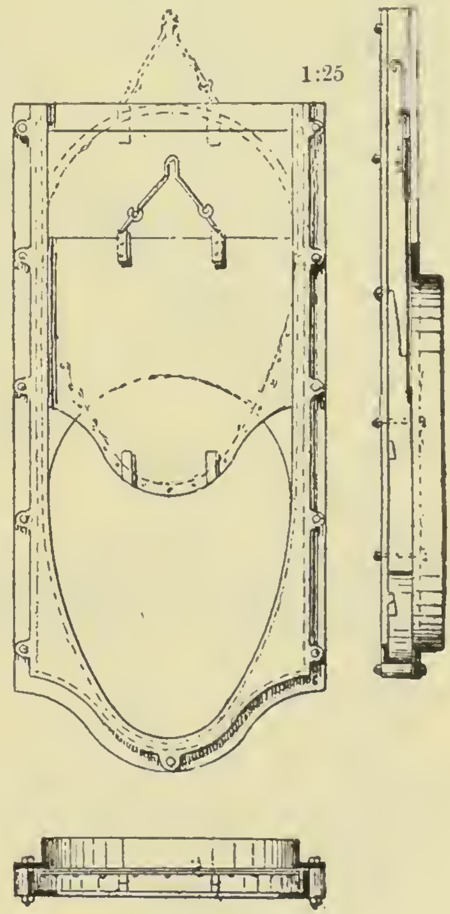


FIG 87.

dotted outline, by turning an eccentric bolt, not shown in the cut, when the rush of the water will throw the gate open as indicated by the dotted outline in the section on *d*. The hinges are slightly out of perpendicular in order that the gate will fall back as soon as the water has returned to its normal level. When it is desired to retain the sewage for flushing, the end of the arm holding the gate is fixed to a shoe which is then driven forward by the crank and gearing until it can be turned on the eccentric bolt before mentioned, bringing the whole

apparatus into the position indicated in the figure. The workmen stand in the niche containing the gears.

Another apparatus quite widely used is shown in Fig. 91. The arm *a* is here attached to a movable rack, driven by the pinion *c*, which is turned by a key *d*, a pawl holding the pinion in position. When the pawl is released the pressure of the water will open the gate. Sometimes the sewer is closed by means of a pinion gearing into a quadrant-shaped rack attached to the frame of the door. But the use of teeth should be avoided as much as possible in such devices on account of the quickness with which they are attacked

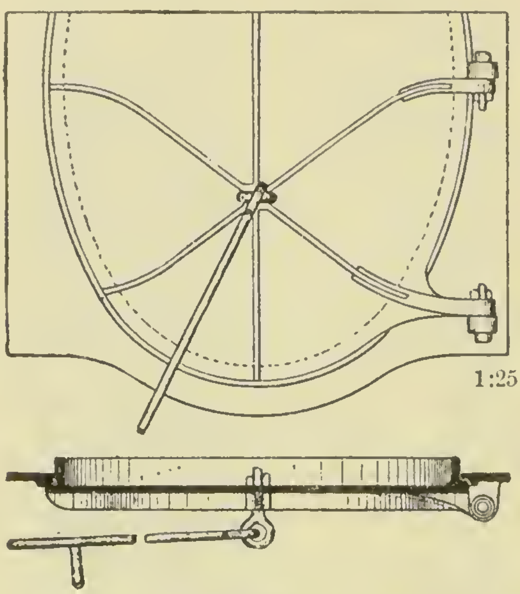


FIG. 88.—FLUSHING GATE AT HAMBURG.

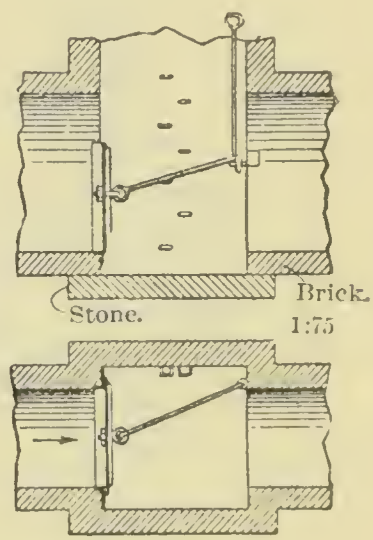
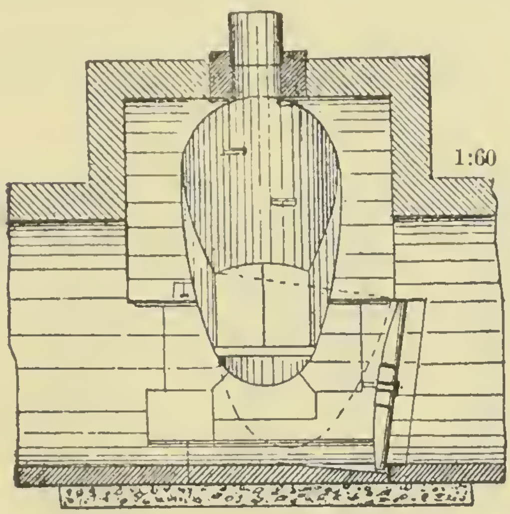


FIG. 89.

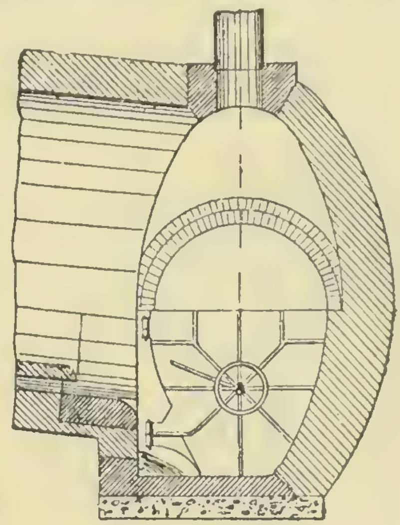
by rust. In very wide sewers it is sometimes necessary to use a gate with two wings.

3. *Sliding Valves*, with mechanical lifting appliances. The form used in a great number of cities is shown in Fig. 92 for small, and Fig. 93 for large sewers. In the latter modification a gear is keyed to the top of the worm shaft and counterweights maintain an approximate equilibrium. Several defects, which have been noticed in this arrangement of parts, have been overcome in the apparatus, Fig 94, made under the GEIGER patents. The worm is protected from dirt and is easily oiled. The guides are faced with bronze and the cover is beveled below, so that a tight joint is formed. In the street cover is an indicating apparatus showing the exact amount of opening. These gates have given good results in Karlsruhe, where they are used on sewers from ½ to 6½ ft.

in diameter. In all valves of this class, the opening is done more slowly than when gates are employed. They are, therefore, best adapted for use with large quantities of water, where a small loss is of no consequence, and have the advantage of delivering the



SECTION ON *d*.



SECTION ON *b*.

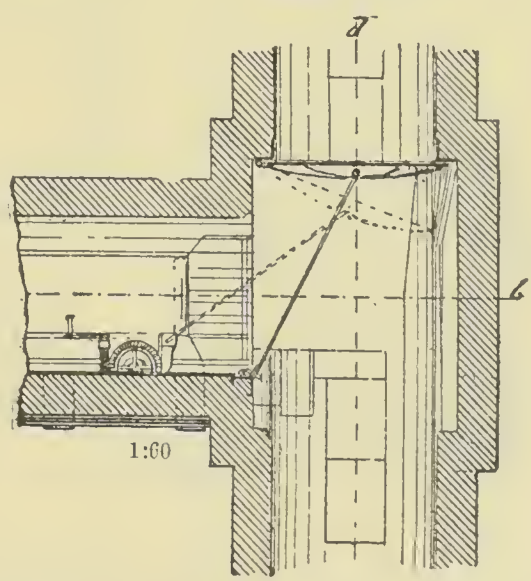


FIG. 90.—FLUSHING GATES, FRANKFURT, DUESSELDORF AND STUTTGART.

water in a fairly steady flow, which carries off the impurities in a satisfactory manner.

4. *Automatic flushing appliances* reduce the expenditure for labor, especially in cleaning house connections. They operate after the manner of intermittent springs. A reservoir is slowly filled with water and sewage, which is suddenly discharged into the sewer, thus causing a flushing wave. The amount of water and period of flushing should be so chosen that the sewer will run

full. The wave will become flatter as it proceeds and the length of sewer that can be cleaned by each reservoir is limited. The whole process is automatic and recurs at regular intervals.

a. The ROGERS FIELD system, Fig. 95, much used in England and America, is usually employed at the dead ends of sewers. The reservoir is fed from the water mains with a valve for admitting water adjusted to give the proper quantity for regu-

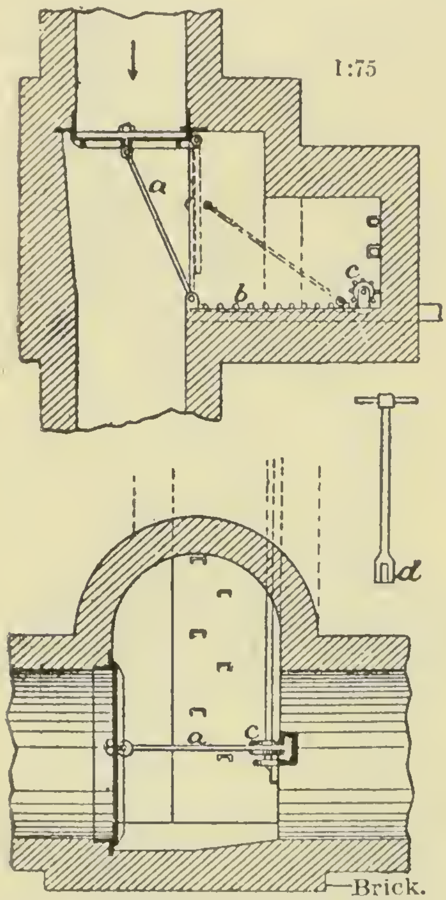


FIG. 91.—FLUSHING GATES, DANZIG.

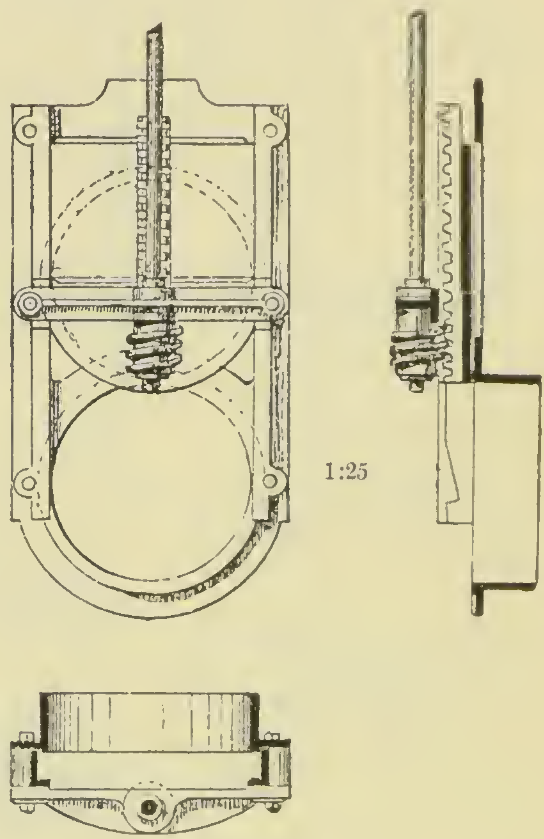


FIG. 92.

lar action. When the water level reaches the mouth of the delivery pipe the reservoir is emptied through the siphon formed by the inner and outer tubes, the discharge being quite rapid. A small quantity of water remains and acts as a water seal against sewer air. In Memphis, Tenn., the cistern holds 53 cu. ft., and is emptied every 24 hours, the discharge lasting 40 seconds and cleaning about 1,000 ft. of sewer.

b. The improved FIELD system is shown in Fig. 96, which represents the apparatus manufactured by Böcking & Co. It was noticed in the older Field apparatus that the thin edges at the

top of the inner tube at times prevented the discharge of the water by a siphon action, the overflow taking place very slowly and only equaling the discharge of the water pipe in amount. Therefore, a small funnel was placed at the top of the inner tube, and the outer tube bent down, as shown in the cut. This arrangement insures a proper discharge by causing the parts to act like an injector.

In apparatus of this kind in Rome, placed every 722 ft. on a

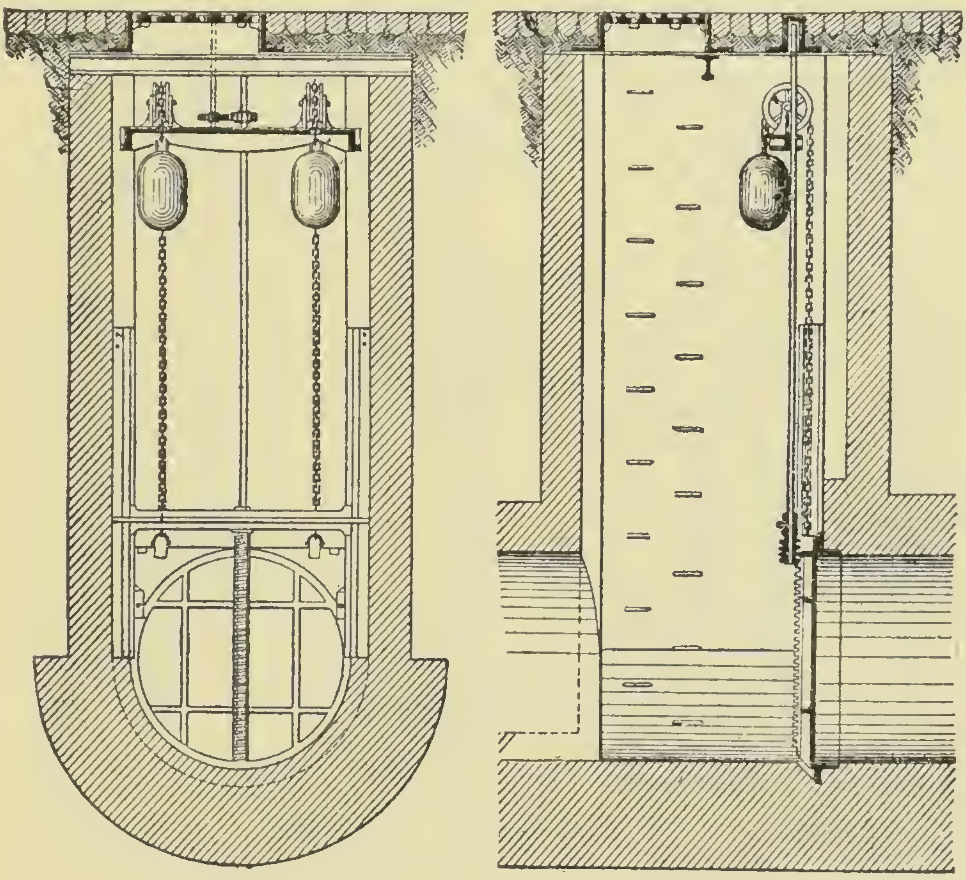


FIG. 93.—FLUSHING PENSTOCK.

sewer previously subject to large deposits, it was found that the discharge of 88 cu. ft. of water twice a day was sufficient to keep the system in good condition. In one district of Paris a number of these reservoirs are used which discharge from 14 to 25 cu. ft. three times a day, while about 600 larger cisterns are used at the dead ends and on the dirtier streets throughout the city, likewise discharging three times daily, or more often if managed by a laborer.

c. The CUNTZ system, Fig. 97. In order to make certain

that the siphon acts properly, the water passes through an injector, *b*, before it passes into the reservoir through the pipe *f*. In this way air is constantly sucked from the space *a*, but is also admitted through *c* until the end of that pipe is closed by the water. Then the air in *a* is removed by the injector and the siphon begins to work. When the reservoir is to be filled more quickly than can be done by the injector alone, the cock *d* is opened. In Karlsbad 140 cu. ft. are discharged in four minutes.

d. System of VAN VRANKEN, Fig. 98. In this construction a box is placed under the siphon. This slowly fills with water

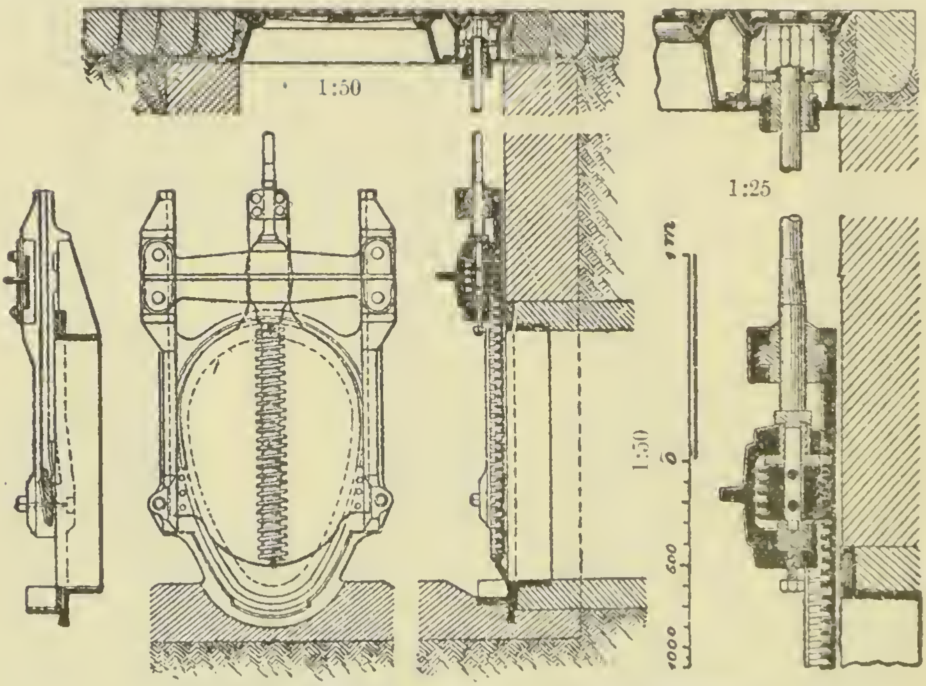


FIG. 91.—FLUSHING GATE, GEIGER SYSTEM.

and seals the end of the discharge pipe. When the box is filled it tips on its supports into the position indicated by the dotted lines, and thus sets the siphon in action. Afterward it falls back into its original position. Unfortunately, it is difficult to examine the box while in place, and on that account the end of the siphon is sometimes carried through the wall of the reservoir into another chamber, as at Regensburg.

e. The FRÜHLING system, Fig. 99. The discharge pipe is closed by a valve which is connected by a rod with a float, *b*. The upper end of the float is connected with one end of a lever, bearing at its other end a box and weight, *c*. While the water is rising *b* and *c* are in equilibrium. Finally, however, the water pours

into the box causing it to sink, and thus opening the valve. The great velocity of the discharge, 13 ft. a second, causes eddies in the reservoir which sweep away all solids. Hence sewage may be used for flushing, which is not possible in the CUNTZ system. This plan is followed at Koenigsberg and Magdeburg.

f. The American system, Fig. 100. In this apparatus an unsymmetrical box is slowly filled until its equilibrium is destroyed

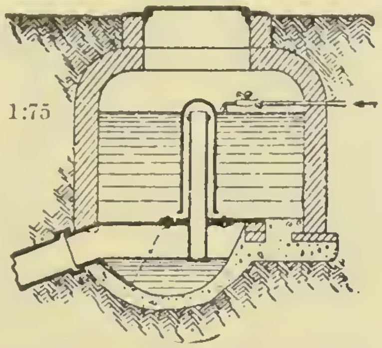


FIG. 95.—FLUSHING TANK, FIELD SYSTEM.

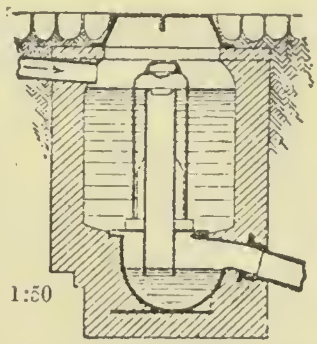


FIG. 96.—FLUSHING TANK, SYSTEM BOECKING.

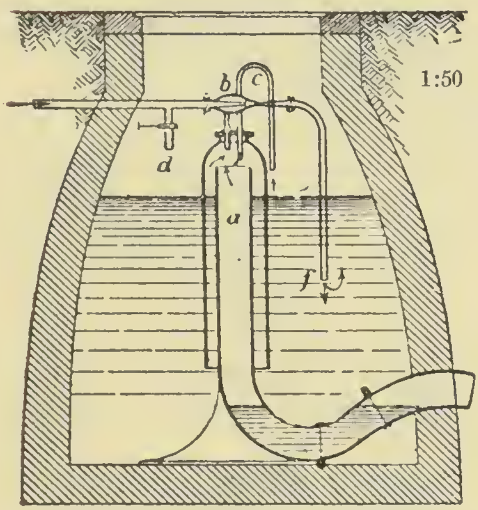


FIG. 97.—FLUSHING TANKS, CUNTZ SYSTEM.

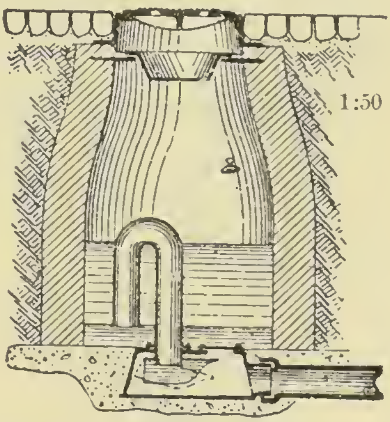


FIG. 98.—VAN VRANKEN FLUSH TANKS.

and it tips on its supports, discharging its contents. The size of the box and quantity of water discharged cannot be very large, thus restricting its use to house connections.

With properly constructed inlets and flushing apparatus, the water carriage system of sewerage ought to prevent the formation of deposits, so that only with very long intervals between flushing will mechanical cleaning be necessary. When water for flushing cannot be had, or is too expensive, other methods must be employed. See note, page 282.

In small sewers or drains a large chain can be pulled back and forth, but a brush is much better, using first one of small diameter and a larger one afterward. Sometimes spherical metallic floats slightly smaller than the section of the sewer are allowed to pass through it. These floats are caught by each deposit and hold back the sewage until a sufficient head is obtained to sweep away the obstacle. Manholes are built in the streets for the pur-

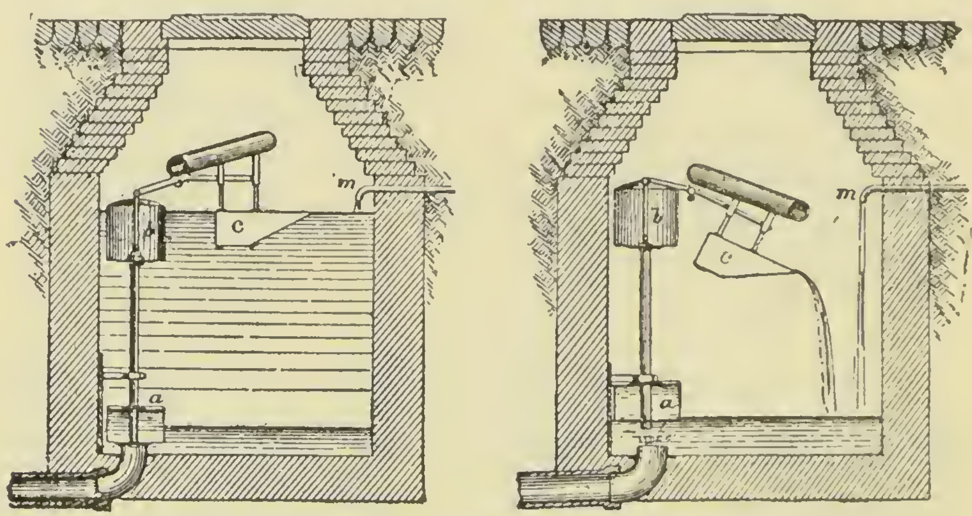


FIG. 99.—FLUSHING TANKS, SYSTEM FRUEHLING.

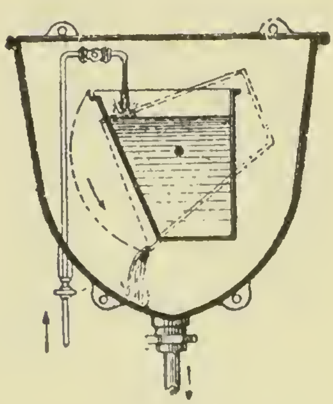


FIG. 100.

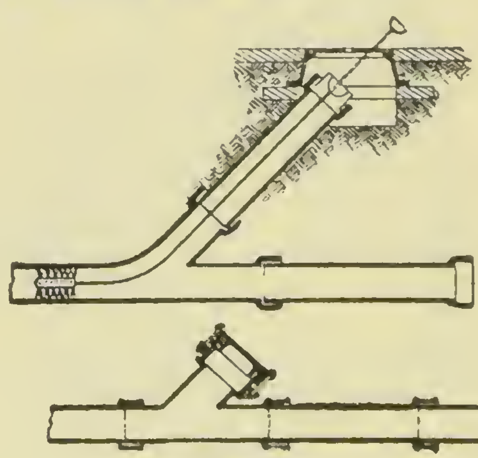


FIG. 101.

pose of employing these various means. In private grounds it is usually sufficient to form connections like that shown in Fig. 101, where the upper cut represents the form of connection for use outside and the other for use inside a house. In Berlin, Mannheim, Wiesbaden and other places, a covered opening, 1 ft. long, must be provided in every house connection within the limit of the private property, for purposes of inspection. In case this opening is under ground a pit must be built in order to reach it.

This is usually done in cellars, see Fig. 116, which represents such an opening in connection with a hinged gate for flushing.

In large sewers the deposits are collected with wooden shovels, and the walls then swept with brush brooms. In Berlin, the gangs for this work consist of three laborers, and each sewer is cleaned every 20 days. In the larger sewers of Brussels and Paris, carts with hanging metal plates are used, Fig. 102. The plates are lowered by the screw rod on the cart until the sewage begins to back up behind, which causes a strong current to pass under the plates and wash away the sediment. The cart is moved along to a great extent by the pressure of the sewage. The deposits are usually collected in dump carts running on the same rails used by the cleaning cart. A somewhat similar plan is followed in Berlin, where a frame is carried by a rolling platform from manhole to manhole. In Cologne, the frames are hung after use on tackles in chambers leading to the sewers.

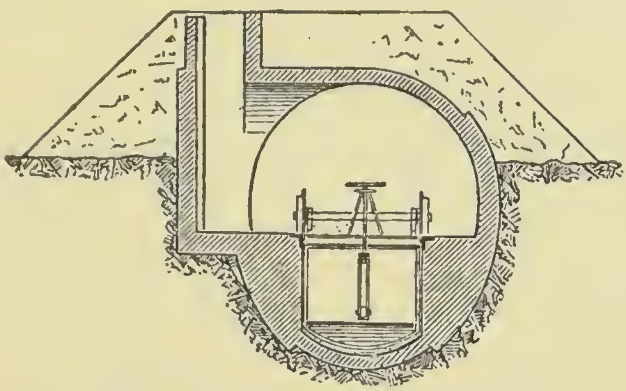


FIG. 102.—CLEANING CART, PARIS.

CHAPTER X.

VENTILATION.

Like water, the air in sewers should never be stagnant, but rather constantly in motion, escaping at some points of the system and being renewed at others. In this manner all the impurities, both suspended and solid, will be more or less oxidized instead of collecting in putrefying masses, as they were at one time believed to do, and the air will not differ materially from that outside. It will contain no injurious gases, only a somewhat larger amount of carbon dioxide (1 to 5 per mille compared with 0.5 in the open).

Moreover, in the circulation of the air, alterations in its pressure will be caused by the inrush of water from houses and adjoining sewers, and equilibrium must be restored as soon as possible, in order that water in the traps may not be blown out or the sewer air escape at unsuitable points. It has, indeed, not yet been proved that disease germs are carried through sewers properly constructed, and the weight of evidence is in favor of the view that the spread of epidemics is entirely independent of sewer air. This may result from the adherence of the germs to the coating on the sewers, and the great dilution of the sewer air when it enters the open. The question is extremely complicated, and, on any account, the formation of deposits in the neighborhood of houses is to be avoided, from their unpleasant odors, if for no other reason. And it is to be remembered that the odors from the regular outlets will become less marked as the circulation in the sewers is more rapid. Here, as in all hygienic matters, prevention is better than cure.

The causes of the circulation of air in the sewers are the differences in temperature and moisture within and without the system. In summer the interior air is cooler and heavier, and hence flows downward toward the outlets. In the cooler seasons it is warmed by the surrounding earth and tends to rise. In consequence of the action of the sun on the various inlets and outlets the heat communicated to the house pipes from chimneys and hot-

water pipes, and the different depths at which the sewers are laid, the resulting flow of air is constantly varying, and a system with its numerous branches and openings has no single main current. Minor influences are the temperature of the sewage, the nature of the sewer walls (affecting the coefficient of friction), and the winds blowing over the different openings. In view of all these influences, which together determine the currents, it is not surprising that the direct observations made in sewers do not always agree. In general a downward flow of air toward the outlet is desirable, as the tendency is then to draw the gases from the houses, with the sewage. Such a motion has been found to prevail in Munich in the street sewers during the summer, while in the house drains the currents are upward, through the escape pipes to the roofs. See note, page 284.

Practically these currents consist of two columns of air of different temperatures and therefore weight, which imperceptibly mingle within the sewers. The outer air enters at several points, its temperature and amount of moisture are altered, and it then leaves as sewer air. That this motion should always be in one direction is of course desirable, but not to be expected. Usually the direction changes frequently, especially when the grades of the sewers are steep. On this account it has been suggested that the sewerage system be divided into zones by contours from 25 to 35 ft. apart, and the air be prevented from rising from one zone to the next above by air valves similar to those shown in Fig. 103. These valves are much like the traps in mines and afford a ready passage to the sewage, but are comparatively air-tight. Such devices do not act as well in practice as in theory, and it appears advisable to confine the attempts at ventilation to preventing the sewer air from entering houses.

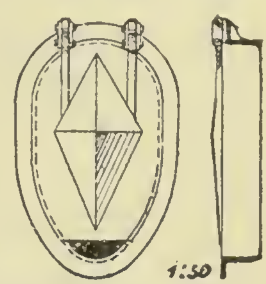


FIG. 103.—AIR VALVE, MUNICH.

The various systems of ventilation for this purpose are shown in diagram in Fig. 104.

1. In the first system, the sewers and the air communicate by means of manholes, ventilation shafts, street inlets, and rain pipes, while the inside connections are all made by water traps. These means of ventilation are rarely all present at the same place: generally the house drains are cut off by a running trap. Sometimes the man-holes are also closed to prevent the escape of possibly injurious

gases, and in such cases the only ventilation obtainable is through the rain pipes. An objection to this system is the unreliability of these pipes. The difference in temperature at their ends may be

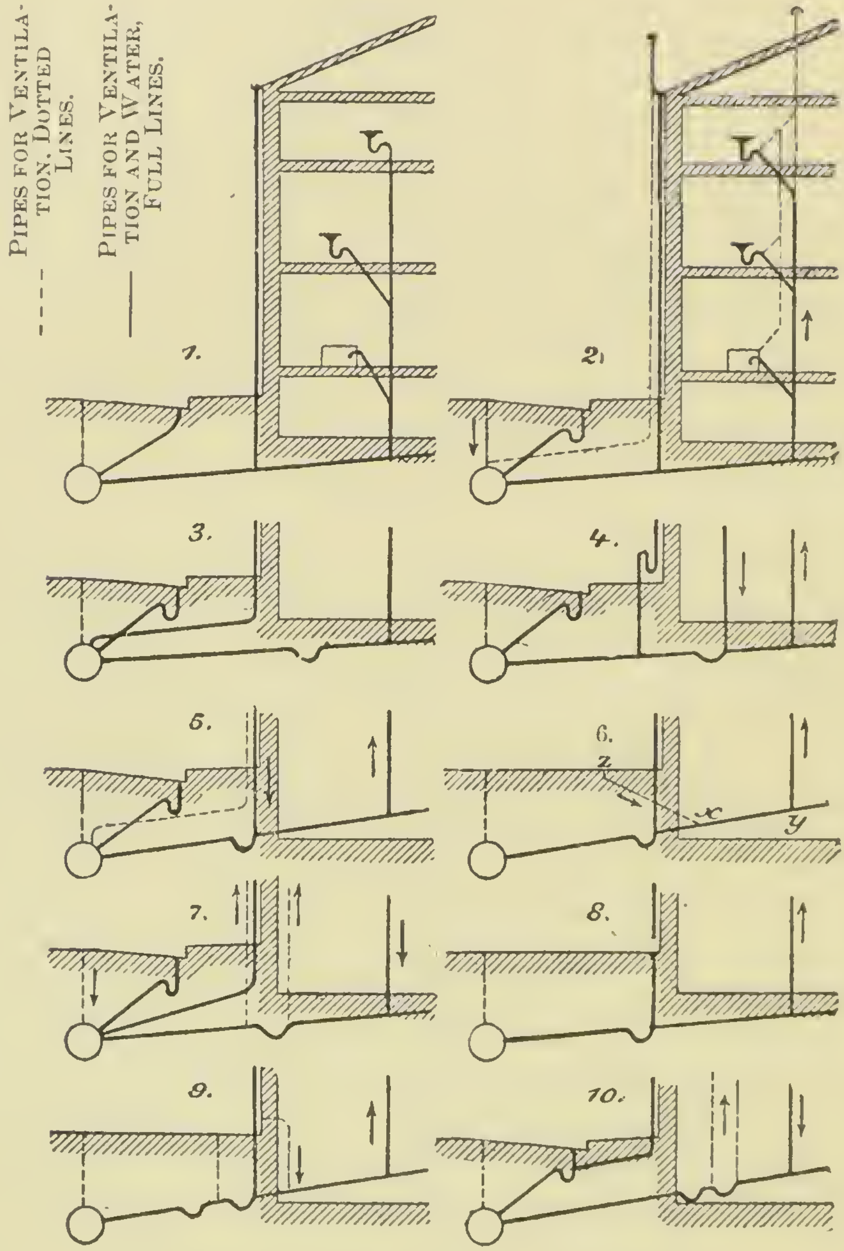


FIG. 104.—DIAGRAMS OF HOUSE CONNECTIONS.

so little that no current will be created ; and, moreover, during a heavy rainfall the water in them will act as a piston for compressing the air and, in place of giving a means of ventilation, will rather tend to cause stagnation. On this account the rain water is often led into the sewers by entirely separate pipes, emptying into the crown, as shown in the third sketch. The worst feature

of this system is the liability of the water in the traps to be blown out by the compressed air in the mains.

2. An improvement is introduced in the second system by prolonging the house pipes upward through the roofs, thus affording a means of equalizing every change in pressure of the sewer air. Since this air would be apt to enter the water of the traps by the inclined connections, it is well to join the highest point of the trap by a suitable pipe with this ventilator, or with a secondary pipe opening either into the higher part of the first or into the open air, as shown by the dotted lines in the second sketch.

This plan is the simplest method of preventing the escape of the water in traps, which is often caused by the suction or pressure of a large quantity of water suddenly falling through the main soil drain. It also serves to remove the gases from grease traps and to prevent the slow absorption of sewer air by the water in little-used connections.

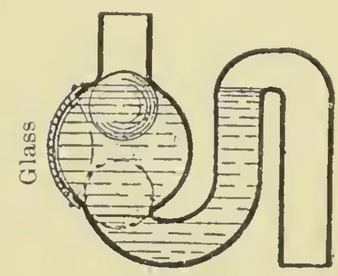


FIG. 105.

The pipes should be of such a size that the friction of the air in passing through them will be quite small. On this account the ventilating pipes should be as large as the soil pipe of which it is an extension, and the connecting pipes should be at least 2 ins. in diameter.

A number of mechanical devices have been tried for preventing the escape of water from traps, but they all fail as soon as dirt collects about them. The best of these is the rubber ball of GERHARD, Fig. 105, which is pressed against an upper seat when there is danger of a blow-out, and drawn against a lower seat when there is any tendency to suck out the water from a trap.

As before mentioned, in the normal circulation of the air, it enters at the street connection and rises through the soil pipes. This current is more certainly maintained when the house drains are specially warmed or placed in the vicinity of chimneys, although the latter method is not always reliable in dwellings. When there are quite a number of trap-ventilating pipes in a house it is often well to connect them to a secondary ventilator built into a special flue in the chimney, as is required in Munich.

In many dwellings the situation of the rooms will permit of two secondary ventilators, one for water closets and one for kitchen and other connections. Sometimes the kitchen drains are

supplied with traps before they join the sewer connection. In this way the closet gases are prevented from entering the kitchen pipes. Such construction, however, does not appear necessary if the designs are suitably made, and the flushing action of the kitchen wastes is lost. But foul gases should never be allowed to come in contact with traps in which the water is liable to evaporate from disuse. These ought to be separately connected with a trap surely filled, such as those used in kitchens.

When it happens that a kitchen drain terminates in a grease trap the latter must have a connection of some kind with the air, in order that proper ventilation may be maintained in that drain. In such a case the circulation in the street sewers is obtained through the soil pipes alone, as in Wiesbaden. Where the closets are not connected with the sewers, the latter have no air connection whatever with the houses and must depend on other means for ventilation.

In a number of German cities the sewerage system is connected with the air by the threefold means of manholes, rain pipes and soil drains. The house pipes are ventilated in this way, as well as the sewers, although the number of dead ends in buildings tends to decrease the actual length of pipe through which the air circulates. In most cases the householder should be required to afford a good ventilation, either by soil pipes without catch pits at the bottom, rain pipes connected directly to the sewers, yard or court inlets without traps, or special ventilating pipes. The latter might be partly paid for by the city, as they directly aid the municipal system.

As already remarked under (1), the rain pipes are unreliable and the soil pipes cease to act as ventilators as soon as their outlets into the sewers are closed. On this account special ventilating pipes are attached to the houses of several cities, as shown by the dotted line in diagram 2. These pipes take the place of the rain and soil connections in rainy weather, and in very narrow streets they occasionally replace ventilating shafts in the streets. They are especially to be recommended for dead ends, and are extensively employed in Wiesbaden, Basel and Danzig. In the latter city over 100 are used, together with some 300 ventilating shafts. They have proved especially valuable in Emden, where the manholes are tightly closed, ventilating extensions not required or used over the soil pipes, and the rain pipes lead to cisterns

where the water is collected for household purposes. Therefore an air pipe was taken from each manhole, under the pavement, and carried up the front of a neighboring building.

3. From the third diagram on, the public and private drains are separated by disconnecting traps in order to prevent sewer air from entering the dwellings. In diagram 3, the rain pipe is not disconnected, as it is designed to aid in the street sewer ventilation. This complete separation of the houses, generally adopted in England and America, is certainly excellent on account of the sanitary protection it affords, but appears somewhat unnecessary when all the details shown by dotted and full lines in diagram 2 are properly designed and constructed, and, moreover, complicates the ventilating arrangements.

In diagram 3 it will be seen that the circulation of air in the sewers depends entirely on the unreliable rain pipes, while the soil pipe has only one outlet into the air, that at the upper end.

4. In the fourth system there are two house pipes—one for the kitchens and sinks and the other of the closets. One of these is located near a chimney, so that its temperature is sufficiently above that of the other to maintain a good current of air through both. Dead ends are to be carefully avoided in this system. In the diagram the rain pipe is disconnected by a trap, as should be always done when its upper end is near a roof window.

5. In this system the rain pipe serves as an air inlet to the house pipes, and a special ventilator is attached to the front of the houses, as indicated by the dotted lines.

6. Since the rain pipe is unreliable in its action, the last mentioned system is frequently replaced by the construction shown in diagram 6, in which a special pipe, opening into a court or under a flight of steps, furnishes a constant supply of air. The points x and y should be some distance apart, the farther the better. When the direction of the current is contrary to that indicated by the arrows, z must be some distance from the house, and the uncertainty as to the direction of this current has led to the introduction of the next system.

7. Here the ventilating pipe is carried up through the house to the roof and a fairly constant circulation is assured by placing one of the pipes near a chimney. This plan has the advantage of removing the gases of a house in the quickest way. In the diagram it will be noticed that the same plan is followed outside the

house as inside, and the ventilation of the whole system is certain, as no reliance is placed on the action of the rain pipe. This system, or the last one, is required in Cologne, with the addition of a secondary ventilating pipe, similar to that shown in diagram 2, when the soil pipe connects with more than two stories.

From the preceding paragraphs it will be noticed that the disconnecting system leads to considerable multiplication of pipes when it is desired to secure as perfect a ventilation as can be obtained by the second system outlined above. The additional security against sewer air is costly, too costly according to German ideas. In America much stress is laid on the interception thus obtained of "unsuitable" bodies before they reach the sewers,

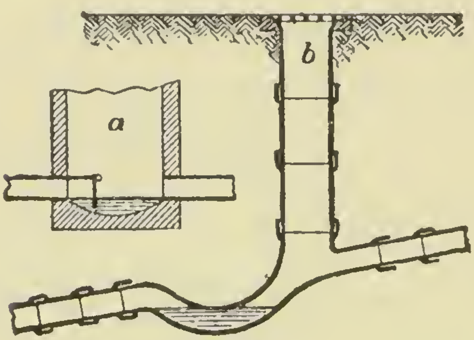


FIG. 106.

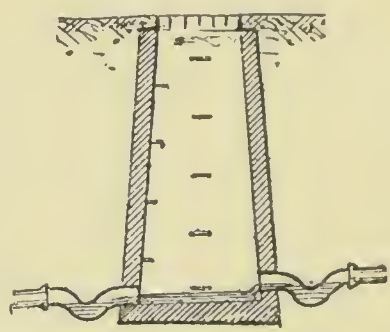


FIG. 107.

but the retention of such bodies near or in a house is more apt to be disagreeable than otherwise.

If it is not desirable to attach the long pipe shown in diagram 7 to the front of a building, there is always a danger of the water seal between the house and the sewer being blown out and the effect of the disconnecting trap thus lost. This has led to the following system:

8. In diagram 8 it will be seen that a large pipe is placed just beyond the disconnecting trap. This is shown on a larger scale in Fig. 106, and consists of either a masonry or pipe shaft. If the water seal is blown out, the sewer air will escape rather through this shaft than by the narrow soil pipes. In this way, also, a constant supply of air enters the soil pipes and aids the circulation in the house. This plan is adopted in Linz, where the shafts are of masonry and the sewer pipe sealed by a flap which can be turned back for cleaning, as shown in Fig. 106 *a*. These shafts are usually located in courts.

9 and 10. In still another system, shown in diagram 9, Fig,

104, there are two disconnecting traps near each other, with a ventilator between the two, which allows the gases to escape when either seal is broken, usually the outer. If the two traps are placed outside a house the construction shown in Fig. 107 may be employed, which also serves for collecting surface rain water. The short open stretch through which the sewage flows is unimportant if there is no tendency to form deposits in the shaft. A

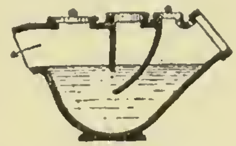


FIG. 108.

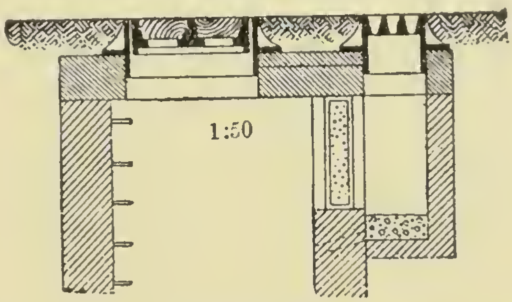


FIG. 110.

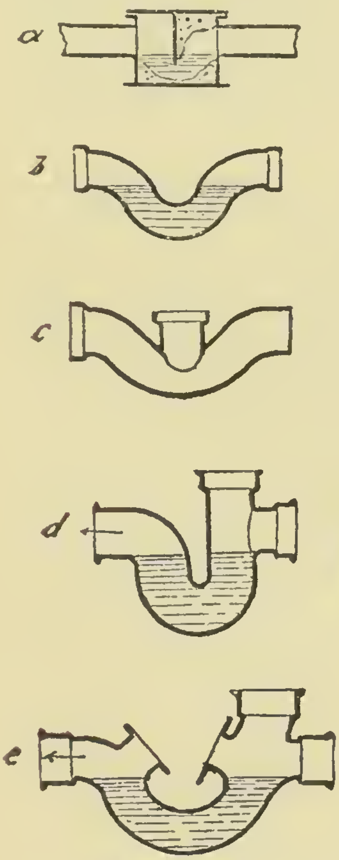


FIG. 109.

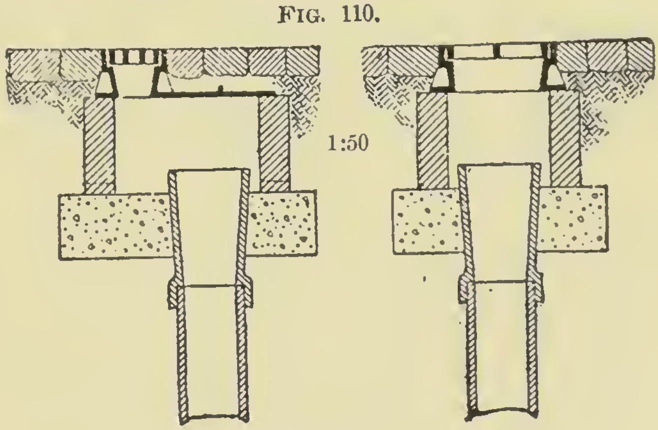


FIG. 111.

modification of the same arrangement may be adopted within a building, as shown in diagram 10, and then necessitates two ventilating pipes, as in the seventh system. The two adjacent traps can be formed by a single casting, as shown in Fig. 108. The tongue on the side next the street is not so long as the other, in order that the seal beneath it may be the first to give away.

In general it may be claimed that the last systems are too refined for the purposes to which they are adapted, and even if all the seals are destroyed the results would not be so extremely bad,

for the traps for each individual house connection would still remain intact, and could not be injured if the inside piping is arranged as in the second diagram.

As regards the details of the water traps before mentioned, it will be seen from Fig. 109 that the angular form *a* causes deposits which leave a curved channel for the sewage. This curved channel is usually followed in making the bends or knees shown in *b*–*e*, Fig. 109. It is always best to leave an opening in the pipe for cleaning, as in *c*, *d*, and *e*. The forms *d* and *e* are especially suited for systems 4–10, in which a vertical pipe for either water or air is connected just behind the water seal. In *e* there are two openings for cleaning the adjacent connections.

The ventilating shafts already mentioned as being located over the street sewers are placed every 100 to 350 ft. They are especially suited for dead ends and for the arched construction shown in Figs. 32 and 37. Manholes and lampholes are adapted for this use; and where they are not properly spaced for the purpose, special ventilating shafts similar to those shown in Fig. 36 are necessary. The construction shown in Figs. 28 and 31 allows all the dirt from the streets to fall into the sewers and should be modified in some manner so that the sewage may be kept fairly free from sand and leaves.

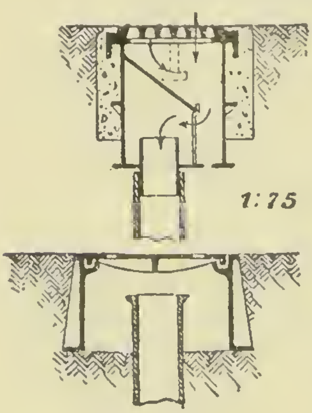


FIG. 112.

In the Berlin manholes, Fig. 30, the cover is pierced with holes near the circumference, and a plate, with a hole in the center, is fixed a short distance below this cover. In America the arrangement shown in Figs. 29 and 98 is employed. Here the holes are in the center of the cover, and a pan is suspended in the center of the shaft. It is sometimes the practice to close the manhole tightly and rely for ventilation on a special ventilating chamber constructed as shown in Fig. 110. In this chamber the sand and leaves are retained while the water drains away unchecked. Where small pipe ventilators are used, the same results are obtained by the arrangements shown in Figs. 111 and 112, the first being a German and the second an American model. In the latter form, the water entering through the grating is allowed to settle into the ground.

It is occasionally deemed necessary to disinfect the sewer air

before allowing it to escape. This is usually done by passing it through charcoal. The best device of this nature is that employed by RAWLINSON and shown in Fig. 110. It consists of a layer of charcoal held between two wire screens. The water entering the ventilator, filters through a layer of sand, and then runs into the shaft through a drain indicated by dotted lines. Generally such screens are little used, not only on account of the check they produce in the ventilation, but also from the fact that the great dilution of the sewer air as it enters the open air practically removes all danger.

There are two other peculiar methods of producing currents which require notice. One is the building of tall chimneys at the highest points of a system, through which the sewer air may escape. There are two such in Frankfurt. They are not heated, and on that account their action is often doubtful. Their dimensions are difficult to calculate so that the currents will be of proper velocity and the chimneys of manufacturing establishments would produce a much stronger current. In every case their influence will only extend to the nearest opening in the system, and their value is therefore much restricted.

Mechanical ventilation has been tried with good results in London. The sewer to be ventilated is open to the air at one end, and is furnished with a suction device driven by the wind. The other end may be low or high, provided only that there is free access to the air. The direction in which the current moves is immaterial. A large sewerage net must be subdivided into a number of small sections where this system is used. In this way the air in the London sewers is renewed 46 times daily. Such a device could be used to increase the circulation in houses cut off by a disconnecting trap, as in systems 4–10, Fig. 104. See note, page 284.

CHAPTER XI.

Effects of Subsoil Water.

Where the regular or relief outlets of a sewerage system lie below the high-water level of the receiver of the sewage, some sort of a gate or valve must be used. The outlets can be left open and the water allowed to back up in the sewers only in places where the system is placed so far below the surface that the effects of the back water are limited to a small area, for otherwise extensive de-

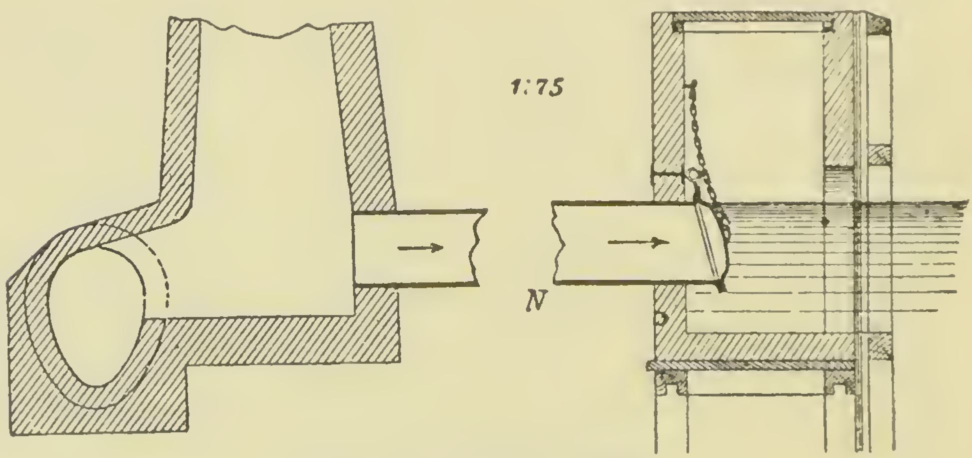


Fig. 113.—Outlet at Danzig.

posits, difficult to remove, would be formed. A common construction is an automatic door or gate, Fig. 113, so balanced that a slight excess of pressure on either side is sufficient to move it. For larger sections the flap should be suspended by links, Fig. 114, and provided with a chain for opening the sewer in case of an accident. The great defect of these gates is their imperfect contact with their seats, allowing a constant leakage and preventing the sewage, when it does escape, from doing so with enough velocity to sweep away the sediment. Hence in large sewerage systems, where a slight increase in the labor expenses is comparatively unimportant, it is much better practice to employ sliding gates, similiar to those illustrated in Chapter IX. Occasionally both swinging and sliding gates are employed, the latter being used in case the former fail to work. Those relief outlets of the Ham-

burg system that discharge into navigable waters are protected from inflowing water by swinging gates, Fig. 114*a*, which open automatically as soon as the sewage has attained a sufficient depth. Moreover, many of these outlets are provided with sliding gates, as shown in the cut, which are useful in flushing. Such a plan has been followed in designing the outlet of the trunk sewer in Hamburg, Fig. 115. While a short length of the outfall remains open to high water, some distance from the outlet two sets of gates effectually shut off the system from the inrush of water during unusually high tides. One set of gates is arranged on the same plan as canal locks, the others are sliding gates. All are operated by hand. Moreover, needle weirs can be used if necessary, somewhat after the plan shown in Fig. 45.

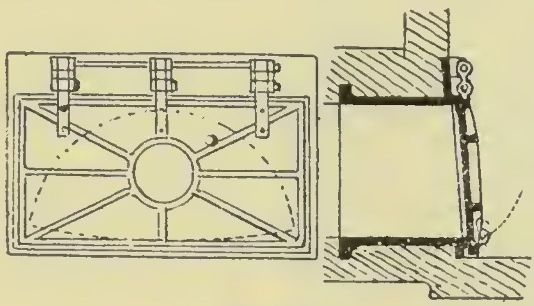


FIG. 114.

Cut-off valves are also necessary for house connections to sewers liable to be filled during floods, which serve as reservoirs a part of the time, or are so small in section that adequate provision has not been made for unusually large rainfalls, or are so near the surface of the ground that the house connections must enter at the side and not the crown. The valves are usually placed in cellars, but sometimes outside of the houses. They are generally automatic, because it is not possible to trust the watchfulness of the householders.

The devices are either hinged doors or balls. The first are illustrated in Fig. 116, showing an easily moved flap, opened by the outflowing sewage but closed by any back water. A cover is provided for cleaning purposes. Another somewhat similar valve, Fig. 117, is

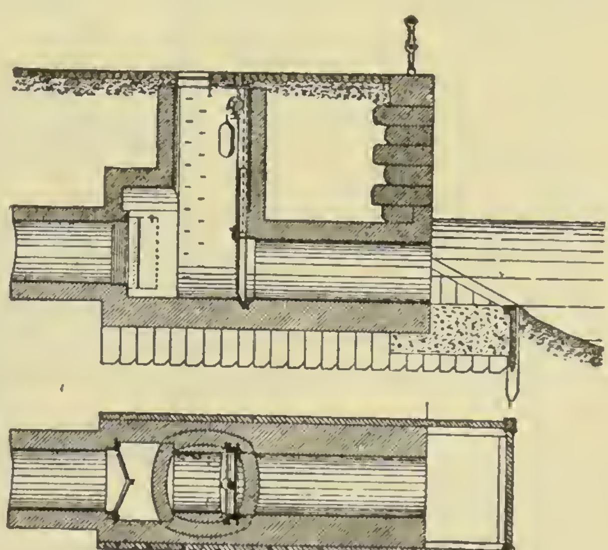


FIG. 114*a*.—RELIEF OUTLET AT HAMBURG.

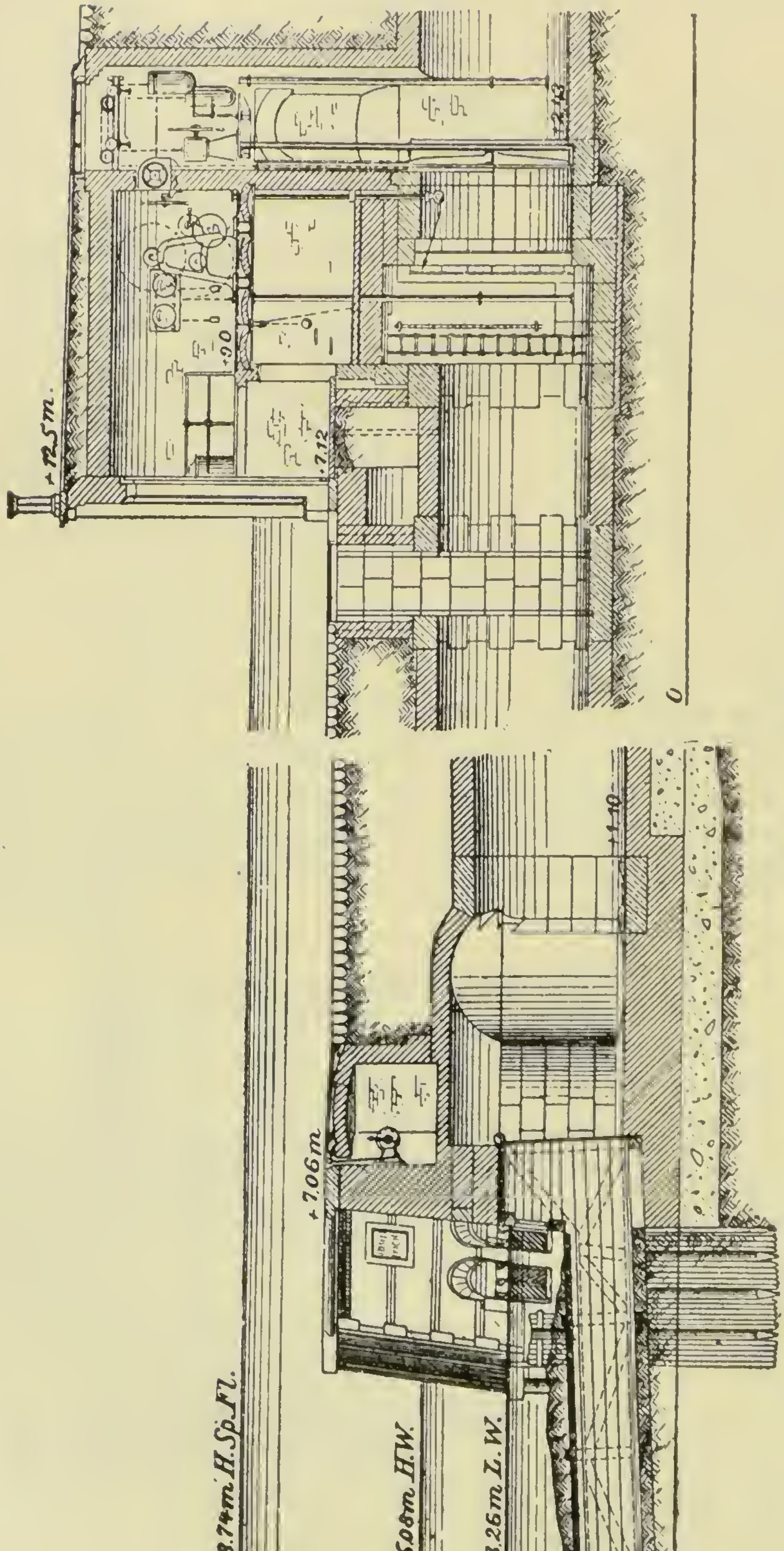


FIG. 115.—OUTLET IN HAMBURG.—ELEVATIONS IN METERS.
1:200

used in Breslau. It is provided with a tongue, *e*, forming a water seal, and a small silt pit, *g*. The top is closed by a cover, *b*, which may be removed for cleaning, the sewage being held back by the flap, *a*, secured by the bent lever, *c*. After cleaning the trap, the act of replacing the cover, *b*, throws the lever, *c*, back and opens the flap, *a*.

Ball valves on the GERHARD principle are shown in Fig. 118. The balls are made either of rubber or iron (hollow), and are occasionally arranged as shown in Fig. 119, which represents a catch basin and fittings, used in courts in Heidelberg and Emden. In the first form the back water presses the ball upward, in the second form downward.

Automatic valves of these types will fail in practice after some use, on account of the dirt which always collects. For this reason many engineers prefer hand appliances, and hold that a forgetful householder should suffer from his negligence. In Munich, both automatic and hand valves are used. The latter are generally flap valves, like those shown in Fig. 85, or sliding gates. The latter have been already explained in Chapter IX. The accompanying cut, Fig. 120, represents a small type much used in Munich for house connections, and differing somewhat from those already illustrated.

When a house and lot have been cut off in this way, the drains act as a reservoir as long as the gates are closed. During a heavy storm the pressure within may equal that without. Then the valves will open and the private sewers will be relieved. In no case should the house pipes discharge into the other drains below the maximum level of the back water in the system; otherwise sewage will flow into the house instead of from it. Hence it will be seen that the best plan would be to cut off, not the entire system of the house and adjoining land, but only those pipes which lie below the maximum water level, as is frequently done in Hamburg and other places. The pipes should be capable of withstanding considerable inside pressure.

Another class of cut-off appliances is necessary in those cities where occasionally part of the surface is submerged by spring tides or floods. The sewers in such places must be protected, not only at the regular outlets, but also at the street and court inlets and deeper cellars, in order that the water rushing in during the floods may not cause excessive backing in the higher part of the

system. All manholes should be protected, therefore, by closely fitting covers. Ventilation is insured by rain and special pipes on or in the adjoining houses. All inlets must be provided with valves, which, however, should not be automatic, as the passage of the water would thus be hindered during the normal condition of affairs. The valves should be operated by hand in one of two methods—either the inlets remain closed and are only occasionally opened to allow the water on the streets to escape, or they remain open and are closed only during floods. The first method is more certain to keep out the flood water, but the second

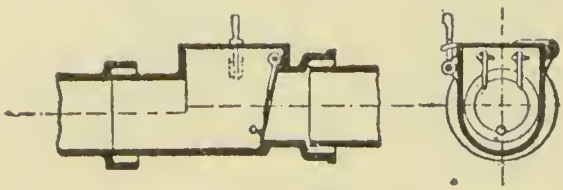


FIG. 116.

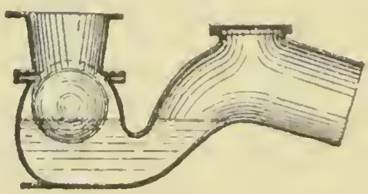


FIG. 118.

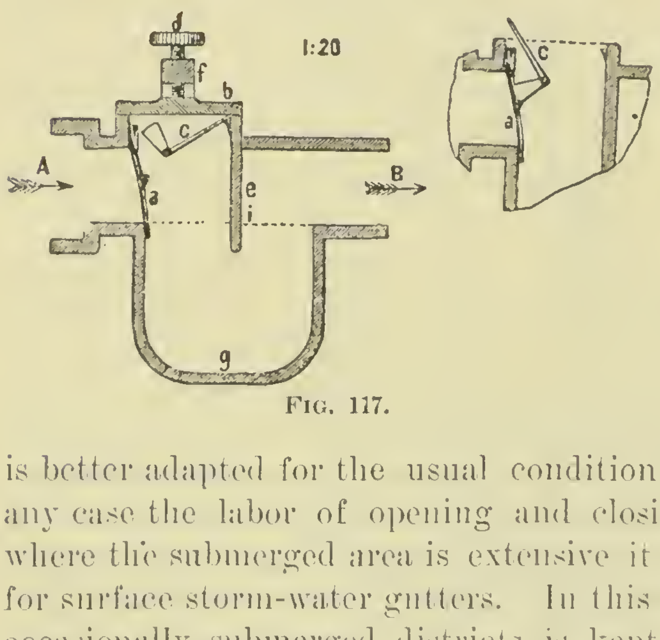


FIG. 117.

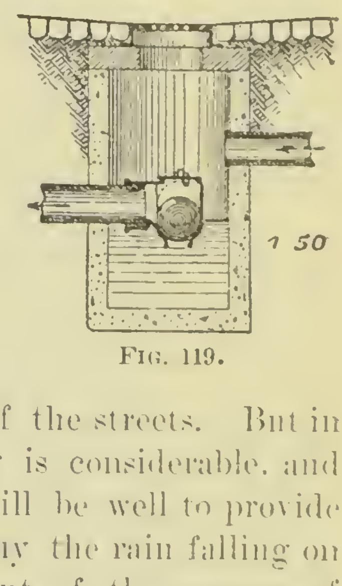


FIG. 119.

is better adapted for the usual condition of the streets. But in any case the labor of opening and closing is considerable, and where the submerged area is extensive it will be well to provide for surface storm-water gutters. In this way the rain falling on occasionally submerged districts is kept out of the sewage of Hamburg, Duesseldorf, and Cologne. If the roofs also discharge their rain water into the gutters, the sewage from such districts becomes entirely domestic, the sewers are able to act as reservoirs for a larger area, and the pumps, if there are any, have to handle smaller quantities than otherwise. Such a plan does not prevent the use of the rain pipes for ventilation, as an inclined connection can be made, as shown in Fig. 121. It would be better to carry a separate ventilator up to the front of the house.

Where the bottom of the cellar is below the level of the ground water, the latter can usually be carried off without difficulty. When the house drains have been laid, there usually remains a loose layer of dirt around the pipes, which serves to carry off the water to some extent. Thus a secondary drainage system is formed outside the regular sewers. In this way the excavations for buildings are easily drained, but the method is liable to dry up neighboring springs and injure wooden foundations. In order to ensure reliable working, the sewers can be surrounded with gravel or be provided with a special drain, as in Fig. 7, or side drains for the purpose may be connected with the main sewer. Sometimes,

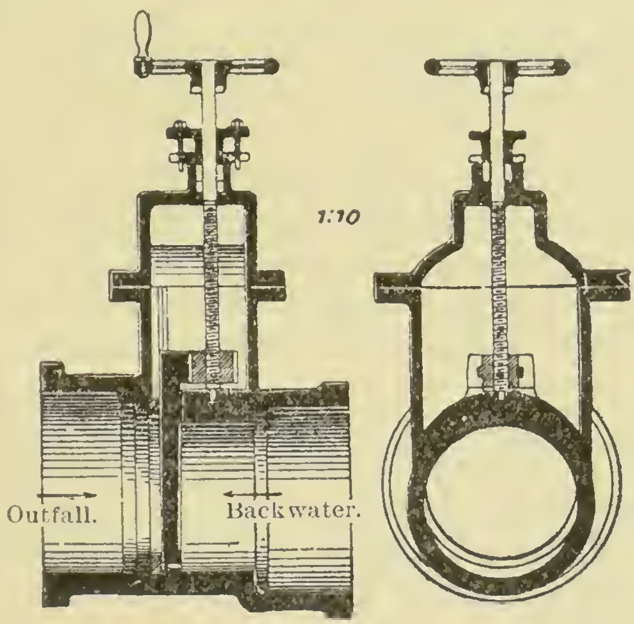


FIG 120.

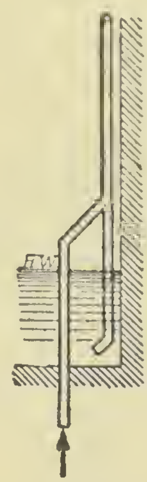


FIG. 121.

when the main system is very open in its plan, special sewers may be used to carry off the ground water.

The regular sewerage system may also be used for subsoil drainage, by having openings in the upper part of the sewers. Such a plan would allow sewage to escape during heavy storms, but the dilution of the domestic sewage is then so great that little danger would result therefrom. But the large quantities of water liable to enter the system through these openings render impossible any exact estimates of the total amount to be handled, and requires a larger expenditure for pumping. On that account a Danzig regulation prohibits the drainage of open lots by means of the regular sewers, although the lots having buildings upon them may be so drained.

Such devices for disposing of ground water are particularly valuable for cellars liable to be flooded during storms. The water is carried off before it reaches the bottom of the cellar by means of small side drains, Fig. 122. If the quantity is too large to be so handled, it will be necessary to shut off the sewer system in the same manner as is done in submerged districts in cities, in order that no evil effects may be produced by the backing up of the domestic sewage. The drains must be supplied with a cut-off valve, which will prevent the ground water from entering the sewers, and occasionally a water trap may be employed, so that in case the sewage does back up into the house all solid matter will certainly be removed therefrom. Care must be taken that this trap is never dry, as it would then be worse than useless; an automatic feed from the water mains might therefore be employed to insure a perfect seal.

The sewers can also take up ground water by endosmosis. The materials of which they are constructed are more or less porous, and allow water under pressure to gradually pass through the walls. This phenomenon has been observed and the increase in sewage caused by it measured. With a head of 6½ ft. an appreciable quantity of ground water can pass through a 10-in. brick wall. This has led to the fear that in the same way the sewage in a system might be diffused into the surrounding soil by exosmosis. Fortunately, experiment and theory are opposed to this view. Chemical examination of soils in the neighborhood of Munich sewers, and at some distance from them, shows that with good construction the infection of the ground from this cause is very slight or totally wanting. Similar examinations in Hamburg, Altona, and English cities have had the same result. Six years after the first researches in Munich a second set was made, and it was found that the effects of exosmosis were even less perceptible than before, probably because the pores of the material were filled. But the oldest sewers, rationally constructed, which have been so examined, were built within 25 years of the time of examination, and it may be urged that after a longer time the pores will again open. Where the soil surrounding the sewers is porous, the escaping sewage would be speedily disinfected by passing through the ground, just as in a filter.

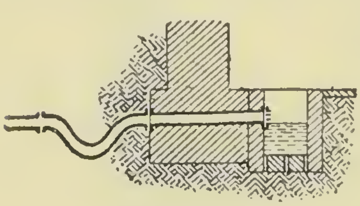


FIG. 122.

Recent investigations in the subject of osmosis have led to more important results. The walls of the sewers form a porous diaphragm between two fluids of different densities, which must experience an exchange of the substances dissolved in them. But on one side of the wall the fluid is in motion, and on that account its exosmosis is diminished or entirely stopped, while its endosmosis is materially increased. These effects grow with the velocity of the current and the porosity of the materials, and may account for the difference in the phenomena observed with still and flowing water. It may be generally assumed that the sewers take up water rather than give it out, and hence a somewhat porous material might be desirable.

But the assumption that two fluids are present is by no means possible in all cases. All sewers are not placed in ground-water districts, and even in damp soils the contact of water with the walls cannot be always assured. The current within the sewers may be very slight, or at times the sewage may remain stagnant. On these grounds the endeavor to have impervious walls is justified and the influence of osmosis, even where it seems to be probable, should be regarded as an over-refinement if made a subject of calculation.

The nature of a sewerage system depends to a great extent on the character of the ground water. Where the latter springs from an unlimited source, like a large river or the ocean, it is of course impossible to construct sewers at any great depth below the surface. No sewerage system could carry away all or any large part of the ground water surrounding deep cellars in such localities.

A perfect drainage of the ground water can be carried out where this water is due only to the rain which falls on the sewerage area. In cases where the subsoil water flows slowly under the whole city, a well-constructed system of drains will have a good effect by producing a depression in the stratum of wet earth under the city, just as in the neighborhood of a well a greater depth of earth remains dry than elsewhere.

CHAPTER XII.

THE SEPARATE SYSTEM.

While the ordinary combined or water-carriage system of sewerage conducts in one channel both rain water and domestic sewage, in the separate or divided system a complete network of pipes is provided for the domestic sewage, occasionally including the ground water, while the rain water is carried off by gutters and storm drains. A part of the storm water is often admitted to the domestic sewage, but such a practice is not consistent with the principle of complete separation, which is often employed in America, and which forms the basis of the following comparison of the systems.

1. *Means of Keeping the Sewers Clean.*—During heavy storms quantities of sand will be washed into the sewers, even with the most carefully constructed street inlets; and although this sand is not of itself dangerous, it may contain organic matter. On the other hand, it is the rain which is relied upon, to a great extent, to wash away the accumulations formed during dry weather. Whether, and to what degree, a preference is to be given to separate sewers, on the ground of greater cleanliness, depends entirely on local circumstances. If the streets are much used and badly kept, if the grades of the sewers are slight, heavy storms unusual, and regular flushing of slight effect, then the divided plan is surely the better; under other conditions it is not so good, especially when the domestic sewage carries with it quantities of scouring sand, which is largely used in the households in parts of Germany. The advantage of the more narrow section and greater velocity, which occurs in the separate sewers during dry weather, is also quite varying. For maximum quantities of domestic sewage alone, pipes of 6 ins. diameter, the minimum in America, might satisfy the requirements of quite large districts. These would run full, or nearly so, once daily, while the "combined" dry-weather sewage, flowing in a circular sewer of 16 to 24 ins. diameter, would have less depth and velocity. But this difference can be reduced by employing an egg-shaped section, since in this the combined sewage at such seasons flows in an approximately semi-circular channel, giving as great a velocity as in a full circular pipe.

Finally, it must be noted that the house connections with separate sewers are more easily made.

Moreover, as regards flushing, the same cleanliness can be attained in the separate system with less water than in the other. Generally the flushing is done by means of automatic tanks; in America, one tank holding from 17 to 35 cu. ft. is allowed for every 200 to 500 inhabitants, and is emptied once or twice daily. This averages about 35 cu. ft. per capita a year. In Berlin, where a large amount of mechanical cleaning is also done, the same amount of water is employed.

When the first separate sewers with automatic flushing tanks were constructed in America no manholes were built.* This led to frequent excavations, and has not proved successful.

2. *Ventilation.*—In both systems a sewer coating and the development of disease germs are possible. In general, the separate system is less exposed to these evils from its more uniform water level, its sections entirely filled at least once a day, and the flushing to which it is subject. On the other hand, the entire surface of these sewers is more often exposed to the organic matter, and thus possibly the germs have really a larger breeding area than in larger sections. Be that as it may, the ventilation of the large sewers is better, and hence the sewer air and the germs it carries with it are more thoroughly mixed with fresh air.

3. *Relations to Streets.*—The increased difficulty of handling a heavy traffic on muddy streets makes the relation between clean pavements and sewers an important one. Both systems have their drawbacks. The street inlets of combined sewers are apt to have dry traps with foul deposits in them, and the escape of sewer air is not unusual. These evils, however, are not so much the fault of the system as of its management. On the other hand, it is claimed that with separate sewers much offensive matter, instead of entering the sewers, is carried away in the gutters, and is apt to create a nuisance. Generally speaking, the cost of street cleaning is independent of the nature of the sewerage system, it making little difference whether the refuse is removed from pavement, from gutters or from catch basins. It would be much more expensive to remove a similar amount of refuse from the sewers themselves, but such a method is practically out of

* This refers to the sewers constructed in Memphis, Tenn., under the direction of Colonel Waring.

the question. Moreover, the flushing of the gutters by the rain has the same effect in both systems; in the combined system the water flows from the watershed to the nearest inlet, while in the separate system it flows a much longer distance and is therefore more likely to cause trouble by accumulating in large quantities.

Where the street traffic will not permit of long gutters the rain water is carried away under ground in the separate system by a special drain. This drain need not be lower than the proper depth to ensure immunity from frost and a proper grade, and is generally above the separate sewer. In case the grades allow, one sewer is generally placed above the other, as shown in Fig. 123, which represents a section in use in Budapest, the upper drain being for brook and rain water. Sometimes the smaller is placed within the other, as in Paris, Fig. 18. The details of construction are the same in both systems.

1:100

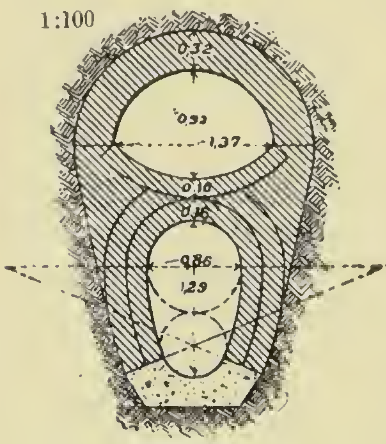


FIG. 123.

4. *Pollution of Rivers.*—Provided actual sewage is not allowed to enter the rivers, the comparison between the two systems in this respect is made by examining the character of the effluent from the relief outlets of combined and the storm water of separate sewers. The nature of the effluent depends upon the amount of cleaning of the sewers in the first case, and of the streets in the second case. Theoretically, all street refuse is carried to the river when special storm sewers are employed, while in combined sewerage part remains in the system. The fact that closet sewage may escape from the relief outlets into the river, which is impossible under the separate plan, should not be of much weight in such a comparison, as the outlets are only used at rare intervals and then the domestic sewage is extremely diluted.

5. *Construction Expenses.*—A financial comparison can only be made after the local conditions have been studied, but it is possible to make a few general statements. Where the rain water can be conveyed in surface drains, and only the domestic sewers are placed under ground, the cost of the separate system is considerably less and may sink to from $\frac{1}{3}$ to $\frac{1}{5}$ that of the combined system. Where the water-courses are favorable but the demands

of traffic or the nature of the grades require an underground storm drainage, the separate system still offers a financial advantage. For the storm sewers may lead directly to the river or other body of water, and therefore require a smaller section than would be necessary for a combined system, with its broad and low-lying trunk sewers for conveying the sewage to a distant outlet.

In many cities there are brooks already covered, suitable after repairs for storm sewers but unfit for receiving combined sewage, as has been repeatedly demonstrated. In a place already possessing a partial or too small sewerage system, it may happen that the best relief lies in using the old sewers for rain water and laying a new net for sanitary purposes.

If it is impossible to divide a city into a number of sewerage districts, it may be necessary in employing the divided system to lay three separate nets—one for domestic sewage, a second for rain water, and a third for ground water. In this case the cost would generally exceed that of a combined system, yet not in the ratio of the length of sewers under the two methods, for the storm sewers could be laid near the surface and simultaneously with those for sanitary purposes. Moreover, the more expensive construction of a separate system in densely peopled cities may be counterbalanced by an economy in the cost of pumps, outfall sewers, settling and precipitation basins which are naturally smaller than when combined sewage must be treated.

6. *Cost of Maintenance.*—The last remarks apply equally well to the running expenses of purification plants, which are less with separate sewers, and the advantages of a more constant duty at the pumping stations and a freedom from excessive quantities of storm water should not be forgotten. Moreover, the separate system generally requires less water for flushing, and this item may result in considerable saving in some cities, although where the water supply is large there is little to choose between the two plans in this respect.

From the above summary it will be seen that, as regards sanitary matters, there is little choice between the two systems. The decision rests upon financial grounds alone, on the cost of construction and maintenance of works under the two plans. At the same time the unpleasant features of the separate system, especially the liability to increase the difficulties of street traffic, must not be overlooked. These may entirely forbid, or at least dis-

countenance, the use of the system. Unfortunately it is not possible to express in dollars and cents the bad effects of dirty streets, and on that account everybody is not competent to judge of the merits of the two plans.

These considerations have limited the application of separate sewers to cities of moderate size, not closely built up, or in narrow valleys with steep grades. The first American city so sewered was Memphis, where the plans were prepared by WARING. Several other places were soon after provided with the same system, the rain water being conducted off in surface drains in every case. A small experimental district has been supplied with separate sewers in Paris, the rain water flowing away in the old sewers. A new system is proposed at Karlsbad, where it is intended to carry the rain water into the Tepl River, flowing through the city, and to have the domestic sewage discharged into the Eger River, some distance off. The separate system is now used in a suburb of Potsdam, and the entire town will soon be sewered in this way. Steglitz, near Berlin, offers an interesting example of a small town employing this system. With a population of 40 to the acre, a daily water consumption of 2.47 cu. ft. a person and one-half of this amount as an hourly maximum, the domestic sewage is only 0.0029 cu. ft. a second an acre, while the rainfall is sometimes 1 cu. ft. a second an acre, and one-quarter of this amount flows away immediately. In such a case, where the storm sewage is a hundred times the domestic sewage,—and this ratio will probably continue to hold,—the sewerage system selected is naturally that with separate sewers, especially where the surface disposal of the rain causes little trouble, as in this case.

The separate system is also of value where the outlets are sometimes closed by high water and the system must act as a reservoir, thereby necessitating as small a quantity of sewage as possible. This advantage is still more marked in "submerged districts" of several cities.

As has been already mentioned, combinations of the two systems have been made, by mixing a part only of the storm water with the domestic sewage. Proper drainage of private property has led to this. When the land extends back some distance from the streets, it is impossible for the larger part of the rainfall to reach the surface drains; and where frost and rains occur together to

any extent, a subsoil drainage is imperatively demanded. But apart from this, a proper sanitary disposal of the house sewage may require all the effluent from a house to pass away through one pipe, which results usually in good flushing. Moreover, it is always desirable to have dry cellars, and the best way to insure these is to have a drain leading to the sewer.* Goettingen has recently constructed a system on this plan, the water from the courts and the rear of houses entering the sewers, the remainder flowing off through surface gutters.

It is possible to employ both systems in the same town or city, not only by dividing the whole area into separately sewered districts, but also by an actual junction of separate and combined sewers. This latter may be accomplished in two ways. In the first case, some of the streets may have combined sewers receiving domestic sewage from other streets where the separate system is employed. The combined sewers will naturally be found in the largest streets, in thickly built localities and in flat districts, while the separate system will be employed where the grades are heavy and the houses more scattered. In the plans for Elberfeld the separate sewers are used in the upper part of the town, the rain flowing off into a neighboring stream and the domestic sewage passing down to the combined sewers in the lower village, whence it goes to the purification works.

In the second method a domestic sewerage net may be constructed and the rain water allowed to run in gutters, but a provision made for combined sewers later, when closer building and increased traffic require it. This plan presupposes that the saving in interest will more than counterbalance the cost of the later system.

Recently an improvement in the separate plan has been introduced by Shone in a number of English cities. He divides the city into a number of separate districts, each with its own domestic sewers, leading to a low point within. The domestic sewage must flow with sufficient velocity to keep the sewers clean. Shone considers $3\frac{1}{4}$ ft. per second during the period of maximum discharge sufficient for the purpose. These plans naturally depend on local circumstances to a large extent. In each "low point" is a reservoir which stores up the domestic sewage, and, on being filled, discharges its contents into higher

* Long before Waring, several English cities—Oxford, Windsor, Reading—were sewered upon a partial separate system.

trunk sewers, lying close to the surface and serving as an outfall system for all the districts.

In this way the difficulties attending flat grades are to a great extent overcome, and the heavy expense of digging deep trenches, of frequent flushing, and of removing deposits is avoided. It is customary to use compressed air in these plants, a central station distributing power by this means through iron pipes to all the districts. The air pipes are two or more inches in diameter. The pumping or lifting appliances may be constructed in many forms, provided that the discharge is automatic and takes place as soon as the reservoir is filled. SHONE invented an ejector, Fig. 124, for this purpose, in which the rising water in a spherical reservoir finally lifts a small bell in the top of the chamber. This bell is connected with a valve, which, on being opened, admits compressed air to the chamber, thus emptying it of its contents. A suitable set of check valves is provided for maintaining the proper direction of the discharge. The air valve is closed when the chamber is empty by the weight of a small bucket always full of sewage. From 11 to 22 cu. ft. can be lifted in this way in 30 to 60 seconds. These appliances form the weak point of the system, for a large number are necessary in extensive sewerage nets, and, if any of them fail to work, the repairs are difficult and apt to require some time. Two ejectors should therefore be supplied at each "low point," requiring a considerable outlay. Leakage in the mains is also liable to occur, and is difficult to locate and remedy.

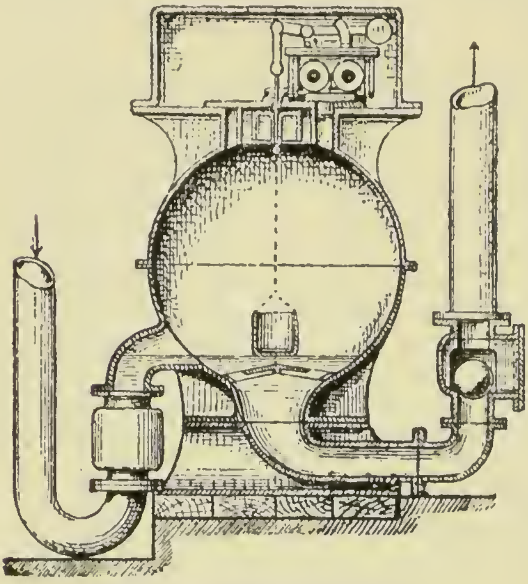


FIG. 124.—SHONE EJECTOR.

It is well known that pneumatic distribution of power from a central station is a cheaper method of running light motors than the use of separate power plants of small size.*

* This broad statement must be taken with some grains of allowance, since under certain conditions the small independent power plants will probably be more economical.—J. M. G.

Moreover, the central station possesses the advantage of a constant duty for the engines, since the pumps can be used to feed large air reservoirs instead of connecting directly to the mains. These ejectors do away with the friction and other losses of pumps, besides being economical of space. On this account they might be used with advantage for other purposes than that mentioned above. The sewage in large trunk sewers might be handled in this way both along the lines and at the outlets. Manufacturing establishments might doubtless at times find their use profitable in draining vaults and deep cellars. They might be used in the combined system, but in that case the quantity of water to be handled would require very expensive apparatus. The English cities in which these ejectors are in satisfactory use include Eastbourne, Warrington, Southampton, Henley and Darlaston. As compared with a siphon, the ejector offers an advantage in allowing the use of sewers nearer the surface, and therefore cheaper. But when a pumping station is necessary at the outlet of the system, it might be more advantageous to employ the siphon than to operate two or more independent power plants.

The latest sewerage plans of LIERNUR recognize the separate system and employ it in three ways—

1. For cities which require the removal of excrement alone, the pneumatic-tube discharge is recommended. See Part III, Chapter X.

2. In cities which require the removal of all domestic sewage but permit the storm water to disappear by surface drains at the outfall, the PETRI method of purification is employed. See Part II, Chapter VI. This combination is employed by Minister of Commerce SCHWARTZKOPF in Berlin, and is therefore designated the LIERNUR-SCHWARTZKOPF system.

3. In cities requiring all the sewage, both domestic and storm, to be carried away under the surface, the complete separate system is to be used. Ejectors are to be employed, and an economical construction thus obtained. In no case are the two classes of sewage to be combined.

CHAPTER XIII.

Cost of Work.

1. Price of *clay pipes* at the works and cost of laying the same, including the expense of laying in the trenches and calking the joints, but excluding cost of transporation and excavation. Prices are for a length of one foot, and are computed from a large number of systems :

Diameter, ins.............	4	8	12	16	20	24
Price at works, cts.......	8-11	15-23	30-45	53-75	83-113	120-158
Cost of laying, cts........	3- 5	5- 8	8- 9	9 12	12- 15	15- 18

2. Price of *cement pipes* and cost of laying, as above ; from the trade lists of Dyckerhoff & Widmann :

	Diameter, ins..........	4	6	8	10	12	16	20	24	32	40
Circular.......	Price at works, cts....	9	12	17	24	32	45	60	75	113	163
	Cost of laying, cts.....	5	6	7	8	9	14	19	23	30	38
Egg-shaped ..	Price at works, cts....	–	–	30	34	39	89	79	124	200	290
	Cost of laying, cts.....	–	–	9	11	14	19	23	34	45	75

Concrete sewers made in place cost, exclusive of excavation, from \$7.50 to \$9.60 per cu. yd. in Mannheim, \$6.90 to \$8.40 in Stuttgart ; in Zurich the average cost was \$8.60, and in Bern \$9.20. The excavation and filling comes to from 47 to 75 cents per cu. yd.

3. Cost per lineal foot of completed sewers, including excavation and similar work, but excluding manholes and inlets :

Table V.—Cost of Sewer Construction.

	Diameter, ins.	Clay pipe or Eggshaped brick sewers.					Cement or concrete.					
		Berlin.	Koenigsberg.	Munich.	Vienna.	Emden.	Augsburg.	Wiesbaden.	Freiburg.	Nuremberg.	Zurich.	Karlsruhe.
		\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$
Circular section.	8	1.06	0.83	1.29	1.14	.45- .61	......	......	......	1.82	1.52	.....
	12	1.37	0.99	1.73	1 52	.60- .83	.76	1.90	1.06	2.13	1.67	1.52
	16	1.82	1.29	2.28	2.28	1.06-1.37	.....	2.28	1.22	2.54	2.05	1.88
	20	2 75	1.67	2.74	3.04	1.52-1.82	....	2.66	1.37	3.04	2 43	2.25
	24	4.10	2.43	......	3.80	....	3.04	......	1.52	......	.. ..	......
Egg-shaped section.		Berlin.				Stuttgart.	Stuttgart.					
	24	4.56-10.62		.....	3.04	....	..	3.43	1.86	.....	..	3.43
	31	6 84-13 60		4.33	4.18	4.04	4.12	4.19	2.52	5.04	4.81	5.34
	39	9.00-15.95		6.38	5.[illegible]2	5.95	4.42	4.96	2.97	6.81	5.72	
	42	10.56-20.10		7.30	6.47	6.86	6 56	5.72	3.66	8.70	6.87	
	55	12.15 23.55		9.35	......	....	......	......	.. ..	10.66	7.63	

The prices for Berlin are on the authority of HOBRECHT. The smaller values are for masonry sewers in good ground; the larger for masonry sewers on concrete foundations between sheet piling.

4. Price of special work, complete, varies considerably in different cities. Street inlets, \$25–\$45; court inlets, \$10–\$15; manholes, \$38–\$75; lamp holes and ventilating pipes, \$13–\$25; flap valves for flushing, \$8–\$15; sliding gates, \$20–\$40; flushing gates, \$25–\$75.

5. Summary of the cost of a number of sewerage systems, including outfall sewers and pumps, but excluding purification works and private house connections. The cost per capita, actual or estimated, per lineal foot of street sewer and per square yard of area drained are all given. Under maintenance is embraced flushing, cleaning, and general repairs:

TABLE VI.—COST OF SEWERAGE SYSTEMS.

CITY.	Length, in feet, of sewer		Cost of construction, dollars.			Cost of maintenanec, in dollars, per capita annually.	
	Per capita.	Per square mile.	Per capita.	Per foot.	Per square yard.	Sewers.	Pumps.
	Ft	Ft.	\$	\$	\$	\$	\$
Augsburg	2.30	153,000	8.75	3.81	0.188	?	......
Berlin	2.30	178,000	12.00	5.18	0.293	0.065	0.1
Breslau	1.31	110,500	5.00	3.81	0.146	0.035	0.0325
Danzig	1.64	68,000	6.25	3.81	0 084	Leased.	
Frankfurt	2.96	136,000	15 75	5.34	0.230	0.045	......
Hamburg	1.64	68,000	9.50	5.80	0.105	0 075	......
Karlsruhe	2.62	136,000	11.00	4.20	0.188	0.05	......
Linz	1.48	93,500	6.25	4.20	0.125	?	......
Munich	2.46	127,500	12.50	5.11	0 209	0.175	......
Stralsund	1.64	178,000	3.75	2.17	0.125	?	......
London	2.79	119,000	17.00	6.10	0.230	0.175	0.075
Liverpool	2.46	161,500	16.75	6.87	0.355	0.10	.
Paris	0.98	76,500	10.00	10.20	0.251	0.15	0.075

The figures for the last three cities are for 1879; since that time the population has increased, and the miles of sewers also, but much more slowly; consequently the relative prices are now somewhat smaller than given above. Reports for 1886–87 were used in preparing the records of the other cities, together with such information as could be derived from a study of the plans and specifications at hand. The expense in Breslau and Munich includes the cost of several old sewers, which could only be ap-

proximately determined. The large amount in Berlin is due to the double sewers laid in many of the wide streets. The relatively short length of sewers per square mile in Danzig and Hamburg is due to the fact that both cities include extensive areas where there are very few buildings.

6. *Methods of Payment.*—In order to cover the cost of construction, the house owners and factories in the sewered districts should be obliged to connect with the system. Each house should immediately lay its connections when the sewers are built in the neighboring streets, or within a short time thereafter: or, in case a system is already in operation, the house drains should be connected during the building operations.

It is generally customary for the drains of houses and lots to be built at the cost of the owners: yet it is the practice in some cities to construct those portions of the house connections lying under the streets by municipal laborers at the cost of the adjoining householders, in order to have all the work uniform. This is especially true in streets which are sewered after the district is already built up. The city then retains control of everything on or below the public streets, and keeps the whole system in order, except in so far as injuries are due to private negligence.

Whatever may be the method under which the public sewerage system is built, there are but two methods by which the expenditure can be met, either by a single tax or a series of annual taxes. The latter method is best carried out by increasing the annual tax to such an amount that the interest and principal may be repaid after a certain number of years. This is not a bad plan when the entire area of a city has been sewered, and the taxes are thus actually proportional to the benefits each person receives. Such a plan, however, is unfair where corporations and the city itself are not taxed. The system has been adopted in Danzig, Breslau, Karlsruhe, Mainz, Mannheim, and Linz. Generally improvements and extensions of old sewers are carried out at public expense, since the public interests are directly concerned. Subsequent streets and districts—built up after a system has been introduced—are taxed for sewerage purposes by the following method:

In the majority of cities the cost of sewers is borne by the residents entirely, they being obliged to pay as soon as connections

are made from their property. Accordingly, the methods of assessing this tax, explained in Sections 7 and 8 following, except in cases expressly noted, apply to the entire city without any distinction between old and new streets.

Each lot sends both rain water and domestic sewage to the public sewers, and hence it might be considered well to lay two taxes—one for the rain water, proportional to the area of the land, and the other for domestic sewage, proportional to the number of residents. But the two classes would be found to vary in about the same ratio, since an increase in the number of residents also tends to be accompanied by an increased area of roof surface. Since the quantity of rain water is generally small in proportion to the domestic sewage, a single tax will be found sufficient. The tax might be levied on the number of inhabitants, but it is better to make it vary with the financial standing of the individuals since it has been found that the richer classes consume more water than the poorer.

7. *Annual Tax.*—In Berlin it is customary to pay an annual tax covering both the interest on the plant, and the cost of its operation. This amount is based upon the actual use made of the sewers by public and private parties, and is fixed annually by the proper officials. The tax is levied according to the value of the abutting property.

Dortmund is another example of this class, but here the tax is based on the house tax. Dwellings paying a tax of less than $7.50 pay $1.25 for sewers, while those houses taxed above $7.50 pay $2.50 for sewers. Connections for cellar and factory drainage are taxed $2.50 additional.

In Goettingen a more complicated plan is pursued. A tax, varying from 50 cts. to $4.50, according to the house tax, is levied for domestic sewage connections, while factories have a special rate, determined by the average daily sewage; being $14.83 annually for each 100 cu. ft. of daily sewage.

Another method is followed in Duesseldorf. Here each lot pays 50 cts. annually for each meter of street frontage for domestic sewage connections without, or 75 cts. with, the discharge of excrement into the system. Where a single payment (see below) has already been made, these figures sink to 25 and 50 cts., respectively. The regular outlet is a pipe of 6 ins. diameter for every 49 ft. of frontage. If the size of the connections exceeds

this proportion the tax is raised. In Augsburg the annual tax is 17½ cts. per meter of frontage.

The water tax also seems specially adapted for a basis of sewer rates, for the amount of sewage is approximately proportional to the water consumption. On this principle the sewer rates in Cologne are one-fifth, in Koenigsberg one-third, and in Stettin one half of the water rates.

The simplest method of levying these taxes consists in charging a fixed annual sum for every connection; 75 cts. in Darmstadt, 75 cts for each house in Reichenhall, with a considerable increase for factories and 25 cts. extra for each water closet.

8. *Single Payments.*—This method of paying for a sewerage system is employed more often than the preceding. It is usually based upon the length of the frontage of the lots. In corner lots the payment is made for the longer side or that on which the connections are actually made. In some cities it is not customary to reckon rain-pipe connections in calculating these taxes. In Hamburg the taxes are assessed over the whole city or on the sewered district, according as the benefits derived are general or local.

In Bern the city contributes one-fifth, and the abutting property is taxed for the remainder of the cost of new or improved sewers. In Freiburg and in Salzburg the city pays one-third of the cost, and the abutting property is taxed for the rest, one-half of the amount coming from each side of the street. In the new streets of Budapest the residents benefited pay the entire cost of sections up to 37×21 ins. in size; for larger sewers they are taxed $2 per meter of frontage on both sides of the street.

This entire system of taxation is open to objections. The location of an expensive main or cheap branch sewer in a street does not depend so much on the character of the residents as on the general sewerage system, and it seems unjust to tax persons quite heavily for work which materially benefits others, who pay a much less amount. Hence a standard or normal system of taxation is much to be recommended, the amount to be officially fixed. The minimum amount may be proportional to the average cost of the smallest sewers, and all the excess paid by the city. From this amount, the tax may be raised until any definite part or the whole of the cost of a system is met by the residents.

In enlarging the city limits of Bremen and Mainz the parties

benefited are taxed for a branch sewer only. In Dortmund the rate is the cost of a 10 in. clay pipe, buried 10 ft.: about $3.75 to $4 a meter, or a trifle less per yard, at present. Fixed taxes per meter frontage are in vogue in Freiburg and Basel ($2), Heidelberg ($2.15), Munich ($3), Aachen ($3), Cassel and Nuremberg ($3.75), Duesseldorf ($5), Frankfurt ($7.50), Halle ($2.25 in old and $3.75 in new districts, with an addition of $1.25 for each connection made while the sewer is building, and $2 for those put in later). Stuttgart has a peculiar rule. Where the entire house system is connected by a single pipe the tax is $3 for each meter in the expression $\sqrt{F}$, where F is the area of the building. If the rear of the building is separately connected, then the tax sinks to $2.50. In Hamburg the tax is $5.25 for built-up and $2.25 for open lots, the latter being taxed $3 when houses are erected upon them. A special tax of $5.25 per meter is placed on house connections laid in public property, and $1.50 for each entrance of a private drain into the sewers.

In some cities new houses built after the completion of the sewers, and making connections with them, are required to pay part of the cost; in Linz $4.07, Dresden $5.65, Karlsruhe $10. The latter amount, the highest of all, is due to the fact that in that city the new residents are obliged to pay for a part of the whole system already in use.

In Goerlitz the tax is $18.75 for one connection, usually covering the whole house. In Aachen new houses with a frontage of less than 26 ft. pay $45; when larger, the amount is $52.50; factories pay special rates. Within the city proper of Wuerzburg the rate is $24.25 per connection; outside the city it is $125 for a house or factory containing less than 20 persons. For a greater number of workmen $5 is charged for each additional person. In Prague a tax of 4 cts. is levied on each square meter of land on which a building stands.

PART II.—THE PURIFICATION OF SEWAGE.

CHAPTER I.

Pollution of Rivers.

The question as to whether sewage may be directly discharged into public water-courses or must first be more or less purified is still a matter of debate in both scientific and official circles. The following remarks are intended to summarize the facts bearing upon the matter.

1. *Character of Sewage.*—It has already been shown in Part I, Chapter IV, that the presence or absence of excrement does not materially affect the character of sewage. The actual presence of such matter does not produce the effects which theory apparently points out as probable. From a chemical point of view, the elements and products of disassociation of excrement are identical with those of the remaining organic substances in house and industrial sewage. Moreover, the quantity of sewage does not depend to any extent upon the method in which the excrement is removed. Hence regulations concerning the disposal of sewage should perhaps apply to all classes, and be based only on the proportions of nitrogen, chlorine, and other elements present.

In the same way, from the point of view of contagion, the possible, although extremely improbable, transmission of disease germs must be regarded. No matter what may be the sewerage system employed, it is possible for excrement to enter the sewage; and it is also possible that this may come from diseased persons. Just as no distinction should be drawn between the hygienic properties of drinking water and that for other household purposes, since one may be as dangerous as the other, so in sanitary matters the distinction between different classes of sewage is not qualitative but rather quantitative, and to be determined oftentimes by microscopical examinations.

There is no doubt that the putrefaction of organic substances is injurious, even without the presence of contagious germs. But putrefaction does not occur in flowing water containing much oxygen.* It is important that no substances already decaying enter a water-course ; and on this account the sewage of a rational system is much superior to that from old sewers, drains, and similar sources. Although the presence of excrement is generally more unsightly than that of other objects, the converse may sometimes be true, according to the degree of disassociation.

2. *Dilution.*—The quantitative relation between river water and excrement is most easily determined in connection with the population, being proportional to it. In a comparison between cities, the nature of the manufactures, character of the residents, and method of disposal of the excrement are to be taken into account.

The minimum amount of water flowing in a river must be the basis of these calculations ; not the minimum occurring once in a century, but that obtained by averaging the smallest annual flow in a number of years—just as in water-supply computations. In the following table all the figures have not been obtained in the same manner, and are, therefore, only approximately equivalent in their nature. The first column gives the proportion of the total quantity of excrement that enters the sewers.

Other methods of comparison can be employed. In Paris 106 cu. ft. of sewage mix with 1,589 cu. ft. of river water in every second ; but there are cities in which the pollution is much greater. In Dortmund an average of 7 cu. ft. of sewage enters the Emscher river every second, while the average flow of that stream is only 31.8 cu. ft. ; and in the Salzbach, below Wiesbaden, the sewage and river water combine in equal volumes. The most impure navigable river in the world is probably the Clyde, into which more than a half of the sewage of Glasgow is poured, and is carried to the sea so slowly that many weeks may elapse before it reaches the mouth of the river.

Many cities have been omitted from the table on account of the lack of current in the water-course or ocean receiving the sewage. Hamburg, Emden, Luebeck, Rostock, Stettin, London, and Liverpool are among these.

In order to determine the amount of dilution that sewage must undergo in order to become innocuous, the so-called limiting

* See note, page 286.

values of potable water (still a matter of dispute) may be taken as a basis of calculation. The average of seven authoritative (German) statements gives 40 grammes of organic substances to each cubic meter of pure water, or about 17.48 grains per cu. ft. This would require urine to be diluted 500 times, although the other requirements of potability do not require such proportions. Hence, for the total daily excreta per capita, amounting to about 648.2 grains of organic matter, 1 cubic meter, or 35.3 cu. ft., of pure river water is necessary in order to fulfill the requirements.

TABLE VII.—THE POLLUTION OF RIVERS.

CITY.	River.	Population, 1885.	Part of excrement entering sewers.	Grade of river, per cent.	Cu. ft. of discharge a second during low water.	Cu. ft. of river water per capita daily.	Average velocity in feet, per second.	Product of last two columns.
Basel	Rhine	70,000	...	0.08	13,600	18,754	3.54	66,389
Brunswick	Ocker	84,000	0.2	0.03	35	35	....	....
Breslau	Oder	300,000	1	0.03	706	212	2.30	488
Budapest	Danube	420,000	1	0.008	24,730	5,085	3.28	16.679
Dresden	Elbe	250,000	0.1	0.028	1.765	600	1.64	984
Frankfurt	Main	154,000	0.7	0.04	2,473	1,377	1.97	2,713
Halle	Saale	85,000	0.2	....	1,059	1,059	....	....
Hannover	Leine	145,000	...	.	424	247	4.92	1.215
Kassel	Fulda	64,000	0.8	0.055	424	565	1.31	740
Cologne	Rhine	160,000	...	0.02	21,189	11,442	3.94	45,081
Linz	Danube	40,000	1	0.012	18 364	39,636	3.61	143.068
Mainz	Rhine	62,000	0	0.012	17,650	24,615	2.39	56,614
Magdeburg	Elbe	160,000	0.9	0.919	4,240	2,295	1.90	4,360
Munich	Isar	260,000	0.3	0.18	1,490	491	3.44	1,699
Neisse	Bielearm	13,000	1	0.25	71	459	3.18	1.460
Nuremberg	Pegnitz	110,000	...	0.04	318	247		......
Paris	Seine	2,000,000	0.3	....	1,589	70	0.43	30
Posen	Warthe	62,000	...	0.014	777	1,094	1.44	1,575
Prague	Moldau	283,000	0.9	0.08	1,059	317	3.94	1.249
Stuttgart	Neckar	120,000	0	0.13	459	317	1.87	593
Vienna	Danube	1,200,000	0 9	0.039	1.132	106	3.94	416
Wuerzburg	Main	52,000	0.8	0.11	1,059	1,765	2.62	4,622

NOTE.—Neisse had a population of 19,500 in 1885, but a third of this number has been deducted for those residents whose houses have sewer connection with the Neisse River in place of the Bielearm.

Organic matter of some kind is always to be found in rivers. Sometimes, even outside of city limits, as much as 5.8 grains per gal. will be found. If a river is supposed to contain 1.2 grains, and a bad class of sewage containing, say, 29.2 grains is emptied into it, then a moment's calculation will show that the water and sewage may be drunk if mixed in the ratio of 23 to 1.

If, moreover, the daily amount of sewage is assumed to be about 7 cu. ft. per capita, and the hourly maximum one-twelfth this quantity, then the conditions for "pure" water require about 322 cu. ft. of water per day per capita, an amount usually supplied.

The objection can certainly be raised to these computations that the limiting amount of organic matter in potable water was not fixed under the supposition that a part of it was human excrement. The amount must be fixed not only by regarding the chemical composition, but also the original source of the substances. Hence there are no definite values to be assigned, and the matter can be settled only approximately. The natural inclination is to exclude all excrement from rivers; but, on the other hand, there are many streams receiving large quantities of such impurities, which do not appear to be injuriously affected.

3. *Self-Purification of Rivers.*—This term is employed to denote the purification which many rivers undergo owing to the combination of the oxygen in the water with the organic matter to form non-organic substances. This union takes place with comparative ease in the case of hydrogen sulphide and other easily oxidized compounds, but the majority of the impurities require the presence of micro-organisms as a ferment. The necessary mingling of air with the water increases with the velocity of the river, and on that account is given in the above table. The simultaneous purifying action may, in the absence of more exact knowledge, be denoted by the product of the volume and velocity of stream, as given in the last column of the table. A comparison of these figures shows how justifiable were the regulations requiring a purification of the sewage of Paris and Breslau before its discharge into the river; while the ordinances in Dresden and Stuttgart prohibiting the discharge of excrement into the sewers appear equally necessary. On the other hand, many cities could probably discharge all their sewage into the neighboring rivers without detriment to any one. In Neisse, where the comparative factor is 1,460, this is allowed by the authorities, and also in Munich, where the factor is 1,699, the sewage may be discharged into the Isar.

All devices like weirs are of aid in purifying a river. The chemical union is effected when a wide surface of sewage is exposed to the air, but the action is much more rapid in rivers where the contact with particles of air is certain. The oxidation

is more rapid with high than with low temperature, but the liability of putrefaction taking place is also greater. The oxidation is, also, much more rapid with fresh sewage than with that which has begun to putrefy. Dissolved organic matter is changed more quickly than undissolved. The chemical waste from factories, the presence of lime or iron in the river bed or in the water, also affect the self-purification. Although some of these foreign substances, especially acids, are antiseptic, they also prevent the action of the micro-organisms. In this respect fishes and aquatic plants are advantageous in a river. The water weeds give off oxygen and take up carbon-dioxide, and are hence active agents in oxidation. This vegetation presupposes a high degree of dilution; in foul water the growth would consist of mold and other organisms attending decay.

The action of all these elements and influences is naturally a manifold one. Observations on the self-purification of rivers have shown very divergent results. While English rivers appear to be almost universally lacking in this power, American and German streams in many cases, especially with dissolved matter, have shown very gratifying characteristics, even as regards the nature of the micro-organisms. The Pegnitz, for example, which receives all the sewage of Nuremberg, is contaminated for a short distance only. In Breslau, while the entire sewage was discharged into the Oder, there was a sudden increase in ammonia, organic matter, and bacteria just below the outlet of the trunk sewer. These things became gradually less, farther down the river, and at a distance of 20 miles from the city the water was as pure, chemically and microscopically, as before it received the sewage.

Where the self-purification is to be assumed as quite energetic, as at Neisse, Munich, and Cologne, the residents farther down the banks will be troubled in no appreciable degree; and the pollution must be excessive which will warrant the interference of such residents with a formerly acknowledged right of the city to empty its sewage into the river.

4. *Effect of Grades.*—The commingling of sewage and river water takes place more slowly with slight velocities than with more rapid currents, and on that account the pollution of standing water is reprehensible. Where sewage is emptied into a tidal-way it tosses back and forth for some time before finally reaching the open sea. This motion would tend to purify the water below

the city, but, also, to pollute that above. Hence a sewerage system discharging into a slowly moving body of water should be provided with an outfall sewer having a sharp, inclined outlet below low water and, if possible, a prolongation to the lowest part of the bed or channel, as shown in Fig. 125. The cut represents the outlet of the system at Halle, where an iron pipe, braced between piles, carries the sewage to the middle of the Saale River. In Fig. 115 the entrance to a long outfall of this kind, made of beechwood, is shown. The outfall lies at right angles to the shore, is about 230 ft. long, and has a grade of 5 per cent. Such an arrangement offers the additional advantage of an always submerged outlet, insuring a freedom from the bad effects of winds on the ventilation of the sewers.

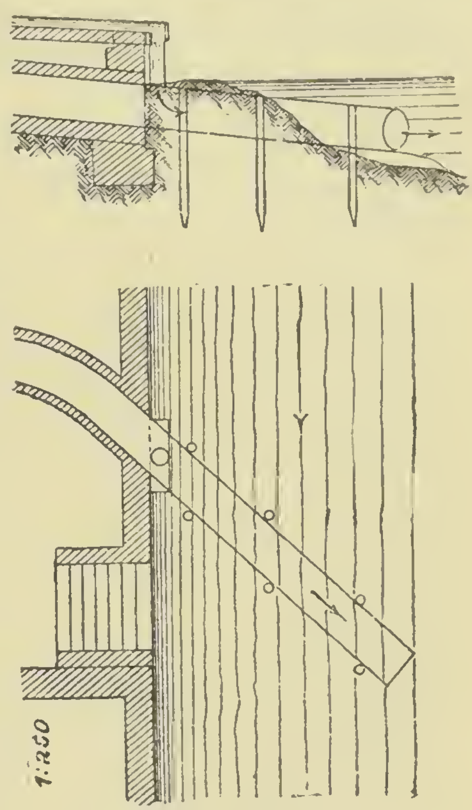


Fig. 125.

In spite of all these precautions the sewage never mixes immediately with the water, but continues on its own way for some distance. Its presence, however, cannot be detected by discoloration or cloudiness in the water if the discharge takes place as just described.

The presence of large floating bodies of organic matter is especially offensive to the eye. Although the specific gravity of excrement, for example, is over 1, nevertheless air bubbles, and even the current, will sometimes keep it on the surface. In addition to the disagreeable appearance of such matter, it requires a longer time, when on the surface, to break up and become dissolved or changed. During falling water such matter and the inorganic substances carried by the river settle on the sand bars and on the banks. This sludge is dangerous, from a hygienic point of view, since, if it dries, the putrefied particles will be blown about by the winds, and the bacteria it contains thus scattered, while if the water again rises, it will be more contaminated than before.

The extent to which such an action might take place, and its consequences, cannot be stated in broad terms. The remedies, or, rather, preventative measures, are: As constant a water level as possible, steep banks, the exclusion of excrement from the river, and a cross-section with the minimum wetted perimeter.

5. *Opposition of Various Interests.*—The use of bodies of water as receptacles of sewage and refuse is as old a custom as employing them for washing, bathing, fishing, or drinking. It is apparently as little admissible to insist upon the absolute purity of a river as to regard it simply as an outfall sewer. Although absolute purity is the ideal condition of a stream, it is practically never attained, on account of the isolated dwellings and clusters of houses along its banks and the boats passing over its surface. It is therefore necessary to compromise the claims of all parties to the use of the water.

As regards the claims of industrial works, the English Rivers Pollution Commission deserves special credit for showing the great loss many establishments undergo from a too free discharge of their waste products into neighboring streams. It is extremely important in many factories to have pure water, since impurities will either destroy or injure the products. The works must accordingly be situated on streams which are, at that point, sufficiently pure. In some manufacturing establishments these considerations have led to a purification of the sewage of the shops before its discharge into the river, while in other places the advantage of an unimpeded outfall was considered to outweigh all other claims. The solids retained in the purification works have often, it should be remarked, a considerable market value.

The case is the same when a river is, or may be, polluted by municipal sewage, which may also come from manufactories as well as dwellings and streets. The use of a river for such purposes is generally subject to heavy damages from communities farther down the banks in case a nuisance arises. If the river is used in these lower places as a source of water supply, the sewage must not produce any evil effects on the water. Only under favorable circumstances and at a considerable expense can other sources of supply be used. All foul matter must be kept away from water used for washing, bathing, or similiar purposes. On the other hand, if a city is compelled to purify its sewage, it is forced to construct expensive works and maintain a sewerage

system under much more difficult sanitary requirements. The city may be benefited by such works, and the river certainly will. Under all circumstances the question at issue is simply whether the general sanitary welfare is better served by improving defective conditions within a great city or those of a scattered population outside it.

There is always a possibility that dangerous disease germs, even with great dilution of sewage, may pass from the river through a filter to a person sensitive to their action. But to expend large sums to ward off any such possible danger is unjustified by our present knowledge of these bacteria; and medical science can give no proof that they are transmitted in undiminished vigor by river water, or are spread abroad by evaporation or precipitation. A certain amount of probability should be allowed in these matters, just as in respect to outlets and ventilators for hospital air and sewer air.

The German Association for Public Sanitation has decided as follows on this subject: "The purification of city sewage before its discharge into a stream is to be desired. Under present technical conditions and with regard to the heavy expense attending the purification, it is recommended to employ the processes only when sanitary evils are to be feared, or disagreeable consequences arise from lack of such treatment, which should in all cases be proportioned to the actual status of the evils."

In many Dutch cities, where sewage is discharged directly into navigable canals, the dilution of the sewage and renewal of the water become important problems. In Amsterdam and the Hague, water is pumped into the canals and their contents thus renewed and purified. In Amsterdam the pumps deliver daily a quantity of water sufficient to cover the entire surface of the canals to a depth varying from 2½ to 5 ins., although the plant is of sufficient capacity to fill the entire canals, if desired. In the Hague the pumps supply daily a quantity of water equal to half the capacity of the canals. Such methods are apparently unsuccessful. Not only must the water be renewed, but the impurities must be prevented from settling, which necessitates a current But any strong current would hinder the traffic on the canals, and therefore no flushing by swiftly flowing water is possible.

6. *Concluding Remarks.*—From the above considerations it will sometimes be possible to determine at once the proper method of treatment. Occasionally it is only necessary to treat

excrement and factory sewage; for as already explained in Sections 3 and 4 it is often sufficient for all purifying purposes to keep the excrement and occasionally the other suspended matter out of the river. The methods of doing this by means of suitable devices in each house, described in Part III, Chapters VII and VIII, are not sufficiently uniform to serve for general municipal purposes; and it would be manifestly unfair to demand a greater degree of purity from one house than another. Hence central purification is more simple and uniform, as well as cheaper, especially as the sludge may often be valuable as manure. But it may be proper for large factories, breweries, abattoirs, or hospitals, which are connected with the public sewers, to have their own purification plant, since the central works may thus be sometimes materially reduced in size or not needed at all. This may lead to use of smaller sewers, less flushing, and increased durability of the material, owing to the removal of injurious chemicals. In many cities it is expressly provided that the industrial sewage must be chemically or mechanically purified before entering the sewers. The need of such treatment must be separately determined for each case that arises. Or such establishments might possibly be required to pay a special percentage of the expenses of a general purification plant. In place of purification it is possible to use dilution as a means of preventing river pollution. Bremen offers an example of a city employing this method. Here the sewage from one part of the place, the Altstadt, mingles with a small stream, the Wumme, and is then emptied into the Weser. The Wumme becomes very foul, being only a small stream, and it is now customary to pump water from the Weser into the city moats, as reservoirs, whence a proper volume may be admitted to the already partly diluted effluent to raise the final ratio of water and sewage to 5 : 1. In this way the total discharge is increased sufficiently to reduce greatly the danger of deposits and odors, and the foul water is more certainly removed. Possibly such a plan could be employed, in whole or in part, in other places.

7. *Official Investigation of River Pollution.*—The appointment of the Rivers Pollution Commission in 1868 was the first official English action on this subject. The Commission made very careful and valuable investigations and proposed certain limits to the amount of impurities which the effluents might carry with them

into water-courses, 13.1 grains of inorganic and 4.37 grains of organic matter in each cubic foot (together, about $2\frac{1}{3}$ grains to the gallon), as well as limits for 8 different chemical elements.

These results are open to debate both as to their form and their quantitative limits. In the first place because they do not treat of the purity or impurity of the river, but only of the sewage, and the considerations mentioned under (2) are neglected. In the second place, it is interesting to note that the above English regulations demand a greater purity in sewage than German practice considers necessary for drinking water. This may possibly be due to the fact that excrement is always supposed to be present in English sewers.

Since these regulations appeared too refined, they were not followed in the preparation of the Rivers Pollution Act of 1876, which forbids in general the discharge of matter from dry closets, city sewerage systems, or factories with injurious effluents. Existing connections from cities and factories may only remain when the best possible means for purifying the sewage is employed. This regulation is enforced with great mildness, and is regarded as an imperfect final resort in case of great necessity. No distinction is made between sewage with or without excrement.

In Prussia there exists a series of decisions of the Royal Scientific Commission of Medical Science, and the ministerial decrees based upon them. The governing principle in all of these decisions is that water-courses must be kept free from continuous contamination by sewage, and many systematic sewerage systems have been delayed in construction or given up on account of this severe ruling. Recently only the best possible purification has been demanded, and the intention is to take into account all the local conditions, especially those immediately connected with the water-course. The decisions now rendered are regarded as less exacting than before, but there is unfortunately no fixed standard, and subsequent decrees may require an alteration in a sewerage system, the effluent of which is not satisfactory. The Commission regards the direct discharge of sewage containing excrement as only allowable in exceptional cases, and generally requires purification by filtration or, experimently, by chemical precipitation. If the excrement is separately removed, then the sewage of small places may flow directly into the water-courses, while that from large towns and cities must be purified, either mechanically or chemically.

In Saxony attention has been especially directed to river pollution by factories, and good results have attended efforts at purification. But it is to be noted that the more industrial the nature of the inhabitants along a river, the greater will be the quantity of offensive matter which the domestic sewage of the villages and towns pours into the stream. City sewage has been considered in but few cases. Since common rights and duties are involved in such matters, the state began investigations of the subject in 1879, and has proposed certain regulations. FLECK has recommended that the limit of allowed pollution be fixed at 10 kilos. of solid sewage a day per cubic meter of river water and per meter of current a second, corresponding to 0.41 ounce per day per gallon per foot of current. These 10 kilos. are approximately the allowance to be made for every 100 persons when industrial sewage is excluded from the system.

Finally, it is to be noted that in every instance relief outlets are permitted to discharge directly into the rivers or other bodies of water, even though some sort of purification is required at the main outlet. This is decidedly illogical with streams of some size, for there is little difference in the degree of pollution whether the discharge from the relief outlets, composed of 1 gal. of waste water to 5 gals. of storm water, mixes with 100 gals. of river water or 1 gal. of dry weather waste water mixes with 100 gals. of river water. The only advantages are due to a possibly somewhat more rapid mingling of river water and sewage, and the detention of the street refuse and similar matter, which enter the sewers at the beginning of storms. It would be much more logical to regulate the matter according to the water level of the river, purifying the sewage during low water and allowing a free discharge at high water. As is well known, heavy storms and full rivers do not always occur simultaneously, and the action of relief outlets is therefore no guide for determining the necessity of purification. Hence it will be easily seen that the whole question of the pollution of rivers by sewage is still far from settled. Relief outlets opening into small streams are by no means excellent devices, but rather necessary evils, as may be seen in Berlin, Vienna, and London.

CHAPTER II.

Chemical Precipitation.

Wherever the velocity of a muddy stream is checked, there is a tendency to form deposits; and if the water of such a river is allowed to stand for a sufficient time it will become clear. Many light and minute particles will remain floating, aided especially by particles of fat and air bubbles. The micro-organisms will not be precipitated to any extent. The water will be settled much more quickly if suitable chemicals are added. The substances added form insoluble compounds with the suspended matter, and attract the floating particles in the water, especially if the latter are at all viscous. In both the mechanical and chemical methods, the same degree of purity can always be obtained, no matter what is the amount of solids present, provided sufficient time or chemicals are used. For example, in Halle careful experiments have shown that the addition of excrement to the sewage, treated by both chemical and mechanical methods, in no manner affected the effluent from the plants.

The chemical treatment was developed in England by a long and costly series of experiments, many of them resulting disastrously. The principles upon which it depends are very simple. The chemicals act upon the floating and dissolved matter, and the micro-organisms are rendered harmless. The precipitate should not be too voluminous, and should be useful as a fertilizer, in order to offset the operating expenses by its sale. The numerous interesting processes that have been applied have not determined the actual cost of the treatment with any degree of accuracy. The leading chemicals are the following:

Lime, burnt from as pure materials as possible, is much used either as air-slacked lime or milk of lime. In the latter form, as a fluid, it probably mixes more easily with the sewage. It is well to use about 1 part of lime to 3 parts of water, and to run the mixture through sieves. The principal chemical change is a simple reduction and precipitation of bicarbonate of lime, which allows the proper proportions of the charge to be easily calculated.

Other small quantities of lime combine with the organic acids, usually of the fatty series, and carbon-dioxide, one of the disassociated products of sewage, to form insoluble compounds. All the small flakes and globules so formed attract the floating particles in the water, and carry them to the bottom.

If enough lime is not present the action will not be so good, since all the portions of the sewage will not be reached by the agent. A greater amount than is necessary to precipitate all the impurities does not increase the efficiency of the process. The proper amount to be added is usually fixed at about 15 grains to the gallon in England, varying with the character of the sewage, and rising to twice that figure with the effluent from factories.

In Essen the quantity of lime necessary to kill the bacteria was found to be 10 grains per gallon, but twice this amount is regularly used. A slight alkaline reaction will be detected when enough lime is present, owing to the very small floating particles remaining in a free state.

Sulphate of Alumina, another material for precipitation, is employed either as a dry powder or mixed with water, preferably in the latter form. In the settling basins the sulphuric acid combines with the alkaline bodies, especially ammonia, the free alumina sinks to the bottom in flocculent form, and carries with it all the floating organic matter. The chemical and mechanical actions are thus of the same kind as when lime is employed, and it is just as necessary to use enough of the precipitant. The alumina sulphate is somewhat more energetic than lime in its action on ammonia. The present cost of the former material is from three to four times that of lime, but could probably be reduced by treating clay stone with raw sulphuric acid.

A combination of the two precipitants is employed in the Coventry process, used in the English city of that name and in Frankfurt. The two substances are added one immediately after the other. The sulphuric acid then acts on the free lime, precipitating alumina and calcium sulphate, two insoluble substances that will carry down with them all the particles floating in the water.

The chemical equivalent of raw, damp sulphate of alumina is about four times that of lime, and the average charge per gallon in Frankfurt is 10 grains of alumina and 2 grains of lime. Some authorities recommend the use of an excess of lime in order

to assure that all the more costly alumina is used. In Coventry 10 grains of alumina are mixed with 5 grains of lime on this account.

Among other precipitants may be mentioned the following, generally used in connection with milk of lime:

Magnesia compounds; for example, the sulphate used in the Roeckner-Rothe process, in which 23 grains of lime and 6 grains of sulphate are employed. A lime prepared from dolomite, containing magnesia and iron, has been proposed. Salts of iron and manganese, especially the chlorides and sulphates, accelerate the precipitation and combine with any hydrogen sulphide present to form iron or manganese sulphides. Slag containing a considerable amount of iron and phosphorus, especially that from the Thomas process, yields a good precipitant on being

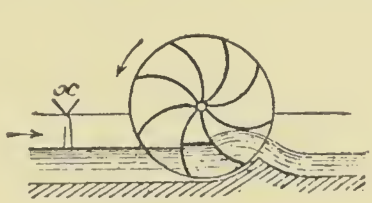


FIG. 126.

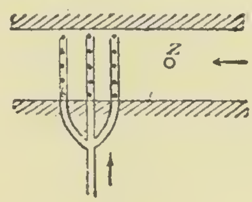


FIG. 127.

treated with acids. Enough lime must be also employed to produce an alkaline reaction.

Soluble silicic acids are used in combination with sulphate of alumina in the Mueller-Nahnsen system. About 17 to 22 grains of lime combined with 2 to 3.5 grains of the silicic acid are used for each gallon of sewage. The compound contains about 40 per cent. of polysilicic acids, 40 per cent. of alumina sulphate, and 20 per cent. of iron oxide and alkalies.

In the starch works at Salzuflen no alumina is employed, the proportions for each gallon of sewage being 29 grains of milk of lime and 12 grains of a polysilicic acid, or the same amount of milk of lime and 6 grains of potassium silicate, or water-glass.

The proper precipitants and their ingredients are to be determined only after a careful examination of the sewage, for its character and quantity change very materially during the day. The sewage of Wiesbaden, for example, was found to contain so many salts that the use of alumina would be injurious rather than beneficial. See note, page 286.

The most simple method of adding the chemicals to the sew-

age is to allow them to flow through a pipe which delivers them over the center of the channel. It would be better to use a pipe with a number of holes, so that there would be several jets instead of one alone. A mixing wheel, Fig. 126, might be placed just below the point x, where the precipitants are added, the wheel being driven mechanically or by the flowing sewage. The lime and other substances might also be forced by a suitable blowing apparatus through a set of perforated pipes in the bottom of the channel, Fig. 127. A salmonway, formed by placing baffle-boards in the channel, can also be employed to obtain a thorough mixing. This method is illustrated in Fig. 138.

Since the quantity of sewage to be treated varies hourly during dry weather, and the change is still more marked during storms, it is very important to be able to regulate the quantity of precipitants added. This may be done by workmen who are provided with instructions enabling them to adjust the valves or gates by which the precipitants are admitted, so that the addition is always approximately proportional to the flow of sewage. This may also be done automatically by means of a float which closes or opens the valves as it sinks or rises; or a water wheel in the sewage channel could be employed which, by its more rapid or slow motion, governs the amount of material added.

When the relief outlets are discharging, or would be, provided there were any, the precipitation process is usually stopped or confined entirely to simple gravity settling, on the principle that whatever escapes at these outlets must also be allowed to escape at the main outfall.

CHAPTER III.

Precipitating Tanks.

Mechanical, or gravity, precipitation is independent of the nature of the chemicals employed, although each inventor combines a special form of apparatus with his favorite reagents. It is desirable, however, to have a suitable arrangement of parts for any or all chemicals. Three types of apparatus are now employed—

1. Flat basins which are filled with the sewage to be purified, and allowed to remain undisturbed until precipitation is complete. The process is known as intermittent precipitation.

2. Long basins through which the sewage flows very slowly. Any one of the basins may be cut out from the others for cleaning, but the sewage, nevertheless, is in constant motion, whence the name of the method—continuous precipitation.

3. Upright tanks through which the sewage rises very slowly.

The size of the tanks or basins depends upon the maximum quantity of sewage to be treated, and is calculated in the same manner as in determining the size of pumping engines. When this amount is exceeded, a by-pass or relief outlet, sometimes opened automatically by means of a float, allows the excess to pass off. All precipitation works must possess a power plant for preparing the chemicals and driving the pumps.

In factories and mines the basins are often simply ditches with a clay bottom. For the large quantities to be treated in municipal works, smooth walls are to be recommended of either concrete or plastered masonry. Protection against frost is unnecessary, since the temperature of the sewage is from 39° to 46° Fahr., and it retains its heat for some time. Roofs are sometimes built as a protection against sun and rain, but on account of the extra cost are not generally employed. The evaporation of the water is insignificant, but the sludge is apt to give off offensive odors while drying, and on that account the works are best located at a distance from dwellings. Where this is not possible, the plant, or at least those parts in which evaporation takes place,

can be roofed over and ventilated by chimneys, as is done in Halle.

1. *Precipitation Tanks Worked Intermittently.*—The tanks are usually of the form shown in Fig. 128, the outlet being from 3.5 to 6.5 ft. lower than the inlet. The bottom is somewhat lower than the outlet, in order to furnish room for the sludge that is thrown down. The inlet should be broad enough to prevent the sludge from being disturbed, and the outlet operated by a siphon or revolving tube, as shown in the cut. The bottom is slightly inclined toward the outlet, and also toward the axis from the sides, as shown in the cross section. A movable pump may be used to remove the sludge, or a single pumping plant may be connected by tubes with each basin. Pneumatic apparatus, similar to that used in removing excrement from houses, has also been suggested. It may be necessary to shovel the sludge into

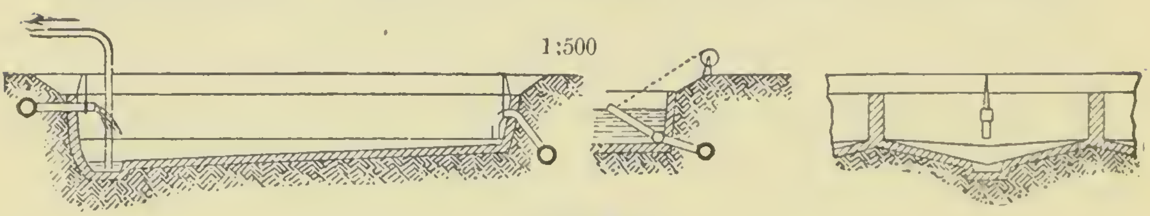


FIG. 128.

heaps by hand, or to dilute it with water, before using the suction pumps.

The operating period of a tank depends upon the time necessary for filling, precipitation, and emptying. The first is proportional to the current and quantity of the sewage, the second varies between ½ and 1 hour, and the third is about equal to the first. An increase in the duration of the precipitation is sometimes made, occasionally to 2 hours, but no material improvement in the precipitate is to be expected from such a course. On the other hand, it is bad practice to diminish the time of precipitation in order to economize space, since organic matter especially requires a certain length of time to settle. Repeated experiments have shown that incomplete purification is not to be recommended on either financial or sanitary grounds. While a basin is standing, another must, of course, be provided to receive the sewage. The size of the precipitation tanks and their number is to be calculated in such a way that, when the last of the series is just full, the first will have been cleaned and ready to receive the sewage. Other things being equal, a number of small tanks are to be preferred to 2

large ones; for with an equal precipitating capacity the time of filling and settling is more favorable, the removal of the sludge easier, and the size, and therefore cost, of the plant less. But with small basins there is the additional expense of dividing walls and gates to be taken into account. In Bradford 34 tanks are used, each 27.6 by 23 ft., and containing about 21,150 gals. In Sheffield there are 30 tanks of about 60,000 gals. each; and other cities have still larger ones.

The sludge is not always removed after each period of precipitation; in fact, it is generally allowed to accumulate for some time. During large discharges all the tanks receive the sewage, since it is probable that this maximum quantity will flow but a short time. In ordinary practice a very short time is necessary for cleaning the separate tanks.

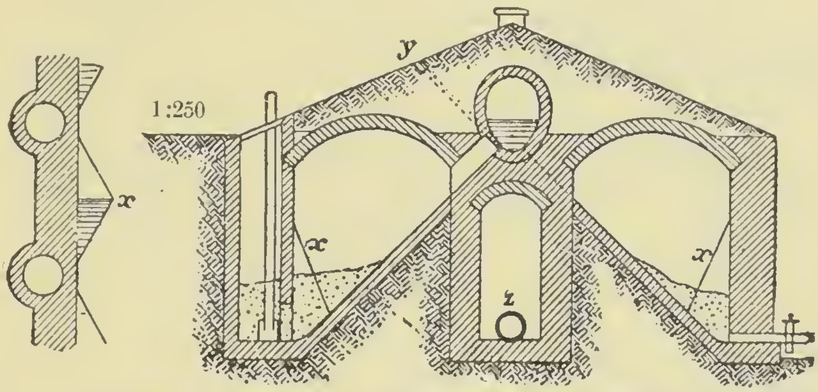


FIG. 129.—PRECIPITATION CHAMBERS, SYSTEM PARJE.

In order to facilitate the removal of the sludge, PARJE has taken out patents for the arrangement shown in Fig. 129. A number of chambers with inclined sides are built below and at each side of the main sewer. The walls are formed by timbers of triangular section, which act as slides, down which the sludge slips to the bottom, whence it is removed by pumps, as shown at the left or by gravity as shown at the right chamber. The sludge can be pushed down the incline by poles introduced through the openings, and the purified sewage is drawn off from the separate chambers through the drain, *Z*.

2. *Tanks Operated Continuously.*—The most common device is the sand pit, Fig. 130, which is built in front of every pumping station, generally in front of chemical precipitation works, and sometimes at the outlet of a system which discharges crude sewage, in order to intercept the large solid matters passing

through the sewers. The general form is circular, Fig. 130, from 15 to 50 ft. in diameter, with a depression in the center from which the sediment can be removed, and also the water drawn off for cleaning. A grating is placed across the pit, in this case diametrically, for the purpose of intercepting all solids, the total area of its meshes being at least equal to the cross section of the inlet sewer. On the other side of the grating is the outfall sewer, and often a relief outlet. In order to keep the grating clean and open, a second grating, moved slowly across the first, may be used as a mechanical scraper. The grating might be hinged and so lifted up for cleaning, or, if large, separate divisions might be moved up and down in suitable guides. There are also gratings which do not reach to the bottom, but only part way, thus intercepting merely those bodies which are floating or slightly immersed. LATHAM has proposed a slowly revolving circular grating through which the sewage must pass, and itself cleaned at a proper place by a stream of water.

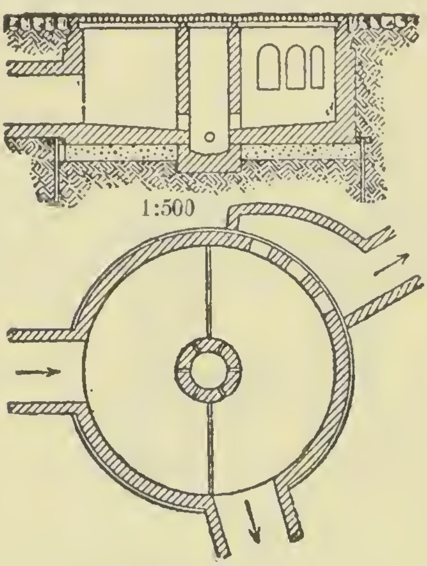


FIG. 130.—SAND PIT.

Tanks are often used in the same manner as these pits, the water flowing continuously through them. The inlet and outlet are on a level, but the bottom of the tank is from 4 to 10 ft. lower, in order to afford room for the sludge to collect. In order to remove this sludge, it is necessary to drain off the water from the tank; therefore at least 2 of them are necessary. In large plants there are a number of these basins, which are cleaned in turn, except while the maximum quantity of sewage is flowing, when they are all used.

As a type of a number of English plants, that at Tunbridge Wells may be taken (see Fig. 131). This is calculated to treat about 265,000 gals. of sewage daily. The inlet is at *a*, the outlet at *b*; both provided with sliding gates. At *c* is a weir for empying the water from one division into the other, or for placing both in continuous action. Each division contains 5 cross-walls, with gratings through which the sewage must pass. The sludge is removed through holes in the bottom of these walls; in

case it will not flow through them it must be removed with a portable pump.

A similar plant has been installed in Dortmund. The water in each division has to travel some 165 ft., and pass through 6 cross-walls with gratings. The section of the tanks, Fig. 132, is better

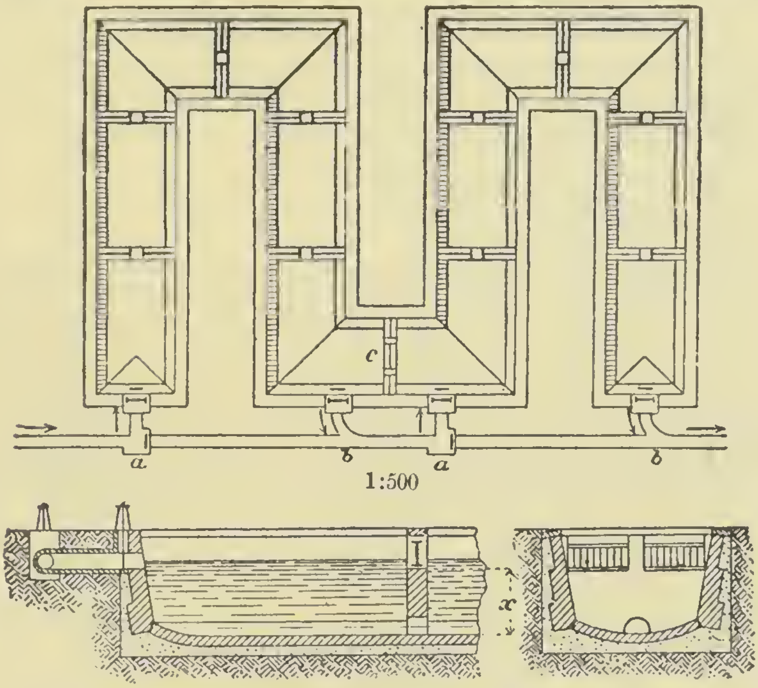


Fig. 131.—Precipitating Tank at Tunbridge Wells.

arranged than that just described. The sludge collects more easily, and a rather rapid incline in the direction of the axis of the tanks causes it to flow better. Nevertheless, it is necessary to resort to manual labor in order to remove all the deposits in the deepest parts.

It is certainly doubtful whether the cross-walls mentioned above are of any actual benefit, for the distance between any 2 consecutive ones is so short that the volume of water below their outlet, x in Fig. 131, may be practically stagnant, and only the upper layers have any motion.

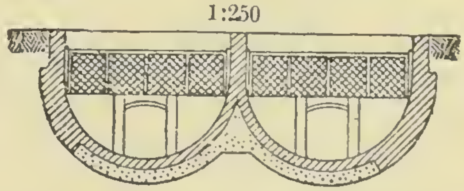


Fig. 132.—Section of Precipitation Tanks. Dortmund.

The section of the moving water is thus quite small, and the velocity, therefore, greater than desirable. If there were no cross-walls, then it would be perfectly allowable to assume that the whole mass of water moved with a very small velocity.

Hence, in the usual construction of these tanks, although it is an easy matter to obtain the correct lateral cross-section, it is unfor-

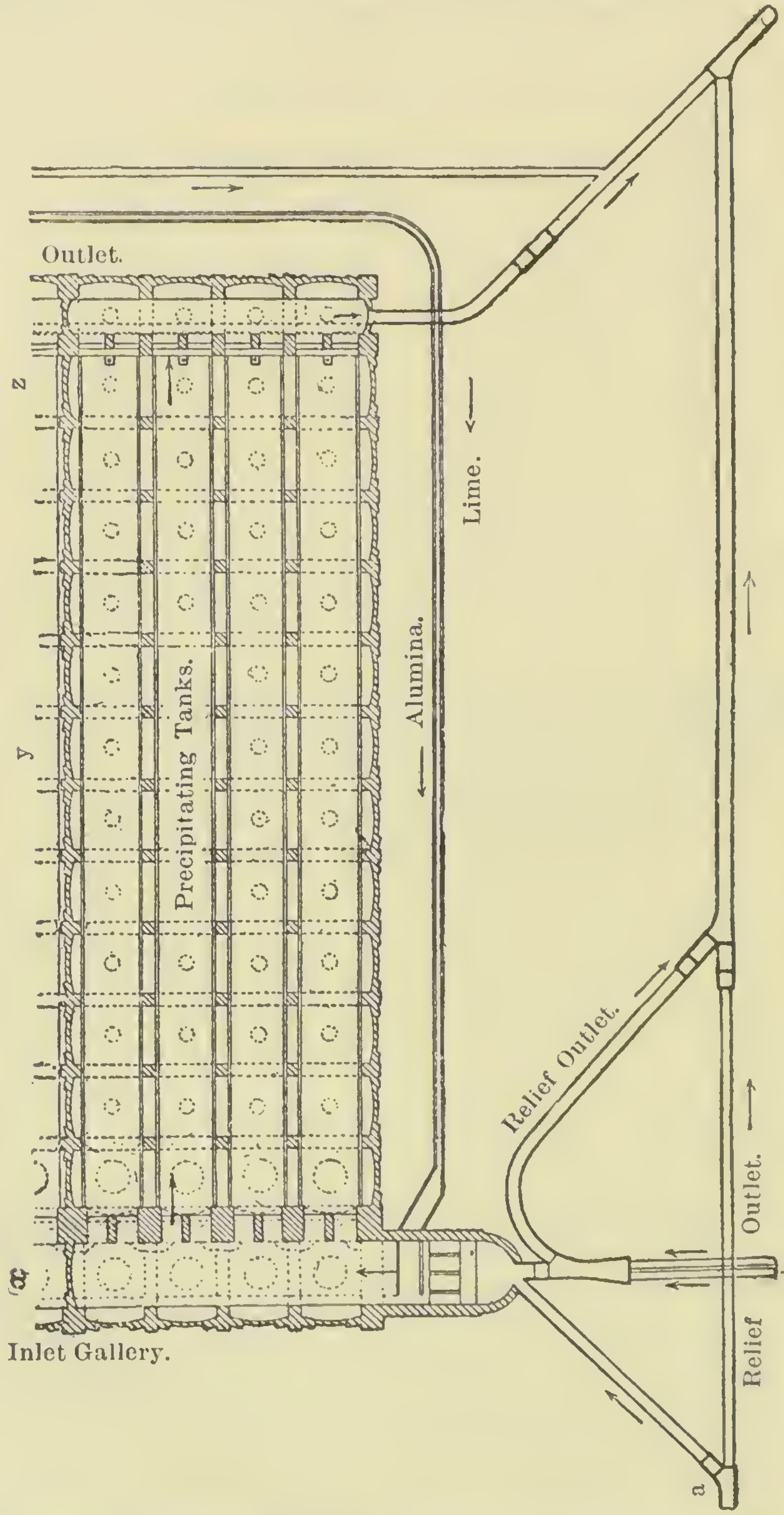


FIG. 133.—PRECIPITATION TANKS IN FRANKFURT.
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tunately much more difficult to determine the proper length. The best rule is to use as long tanks as possible, in order to be sure of

good results, and to counteract the disturbing influences at inlets and outlets. The tanks now in use are generally of sufficient capacity to hold from $\frac{1}{6}$ to $\frac{1}{3}$ of the daily sewage, which remains, therefore, from 4 to 8 hours in them.

The precipitation works, Figs. 133 and 134, at Frankfurt are arranged on this principle, Fig. 133 representing a third of the complete plant. The sewage enters through the pipe *a*, with a velocity of 16 to 20 ins. a second, and through the 2 inverted siphons, *b*, both provided with outlets. The total quantity then passes

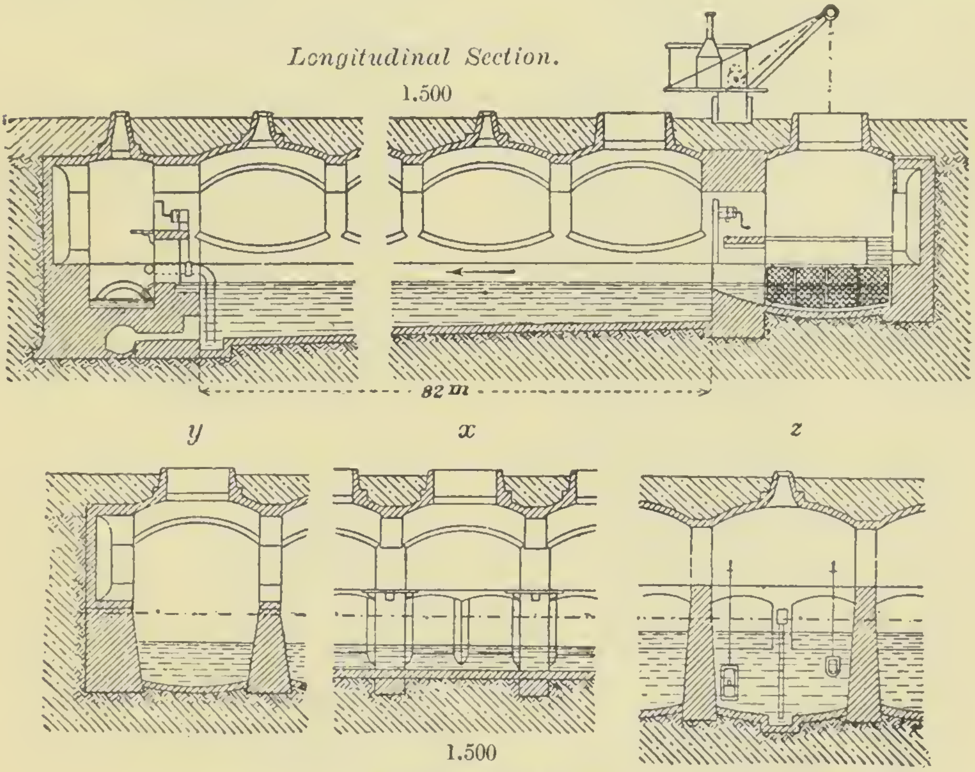


FIG. 134.—SECTIONS OF THE CLEARING BASINS.

through a sand pit with a velocity of 2 ins. a second, then under a plank projecting into the sewage to a sufficient depth to intercept all floating matter, and finally passes through gratings into the mixing channel, where it receives its proper charge of lime and alumina from pipes leading to the machine-house. From the mixing channel the sewage passes into the delivery channel, where the velocity sinks to 1.2 in., and large quantities of sludge collect, which are removed by traveling bucket dredges, without interfering with the working of the tanks. The sewage enters the tanks proper through 2 submerged openings. The depth of water

at the entrance is $6\frac{1}{2}$ ft., and 10 ft. at the outlet; the velocity of the current is from $\frac{1}{8}$ to $\frac{1}{5}$ of an inch. The currents are very sensitive to changes in temperature at different depths, and on that account the sewage is drawn off from the lower layers in summer and the upper in winter. In this way the sewage that has remained the longest in the tanks is first drawn off, an immersion plate being used to regulate the depth from which the discharge takes place. There is only 1.3 in. of water over the weirs which separate the tanks from the outfall chamber, which discharges into the main river. During high water in the river the outfall sewer is closed, and the purified effluent removed by pumps. The 4 tanks shown in the cuts were calculated to dispose of a normal dry-weather sewage of about 4,760,000 gals. daily, or 31.7 gals. per capita. Each tank has a capacity of 291,000 gals., about a fourth of the quantity which passes through it daily. The average amount of sewage treated daily is 7,136,000 gals; the maximum amount is 9,515,000 gals. When such quantities of sewage pass through the works, the velocity is naturally greater than when the dry-weather flow is taking place. The relief outlets prevent the precipitation process from being hurried too much.

The tanks are cleaned by drawing off the water to the level of the bottom of the outfall chamber, through gates at different depths (see Fig. 134, *Z*), which empty into a drain below the chamber. Whenever the effluent is at all turbid the gates are closed, and in this manner all the sludge is collected in the tanks, from which it is pumped. It is sometimes necessary to shovel the heavier parts away. There are also a number of openings in the arches over the tanks, through which the sludge may be removed by bucket dredges.

The plant at Wiesbaden, Fig. 135, is a transition type between the system just described and the upright tanks to be explained later on. It was designed on the basis of a dry-weather sewage of about 1,718,000 gals. daily, and has 3 settling basins of 178,400 gals. capacity each, 2 of which are generally in use and the other being cleaned. Hence, the duration of the water in the settling tanks is $2 \times 178,400 \times 24 \div 1,718,000 = 5$ hours, corresponding to a velocity of only a sixth of an inch a second. At present the velocity is generally greater, since the sewerage system still contains a number of brooks, and the amount of discharge to

be treated is about 6,343,000 gals. The sewage first passes under immersion plates and through gratings into a delivery channel, from which it flows into the preliminary tanks, through mixing channels where the chemicals are added in the manner shown in Fig. 127. In these preliminary tanks the sewage is

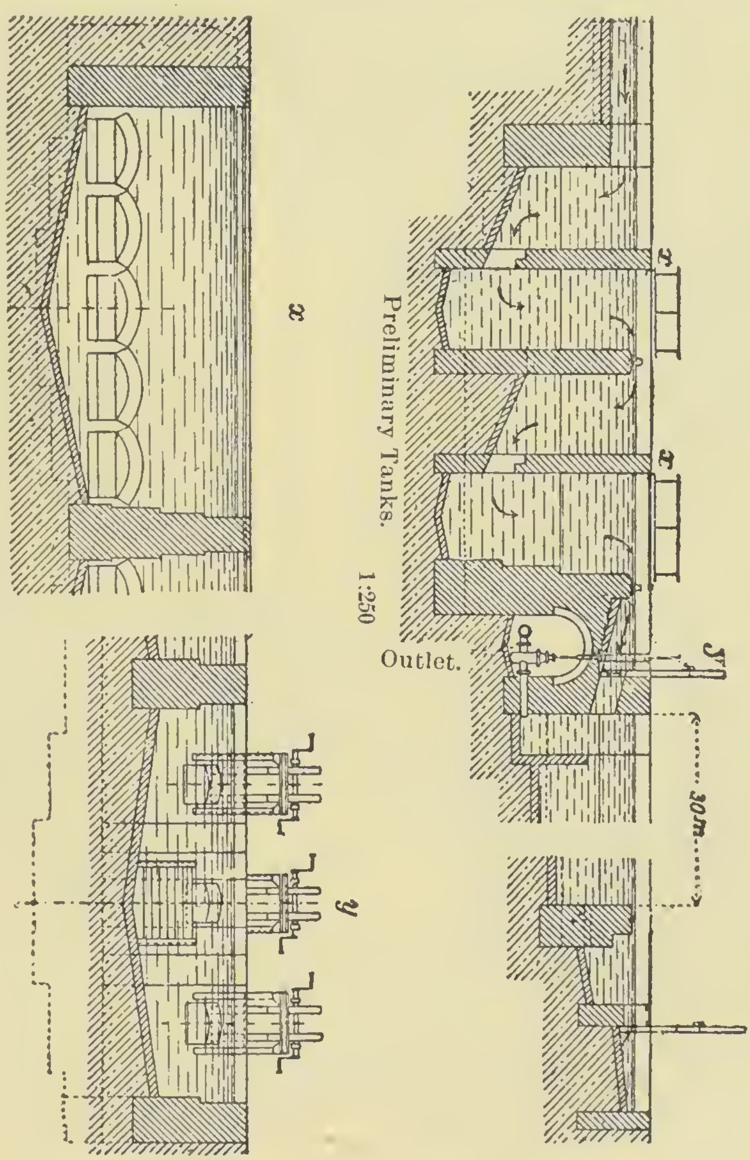


FIG. 135.—PRECIPITATION TANKS IN WIESBADEN.

obliged to rise twice (see Fig. 135), and is thus freed from much of the sludge present. Finally it passes through 3 submerged gates into the tanks, from which it flows over 2 small weirs into the outfall channel. The sludge is pumped from the preliminary tanks without shutting them off. This is done by means of a suction hose leading to a stationary pumping plant. The main

tanks are cleaned by draining the water into a special outfall sewer for the purpose, and then removing the sludge by a suction pipe from the pumps.

All flat basins are open to the objection that the sludge may ferment and the gases thus given off will rise and prevent the desired precipitation, even infecting the air at times. This action would also diminish the effect of the chemicals added; and it is therefore best to remove the sludge soon after its precipitation, without interrupting the flow of the sewage, if possible. Moreover, the extensive area of the tanks should be covered, to

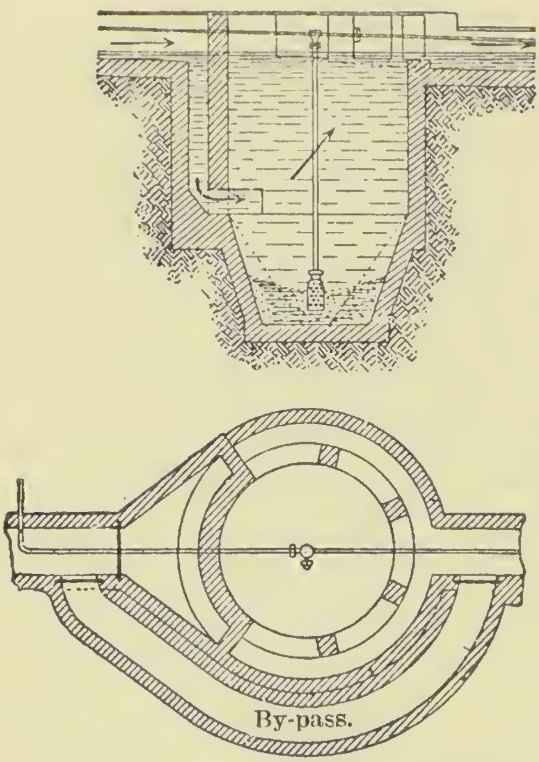


FIG. 136.—PRECIPITATION TANKS IN HALLE, MUELLER-NAHNSEN SYSTEM.

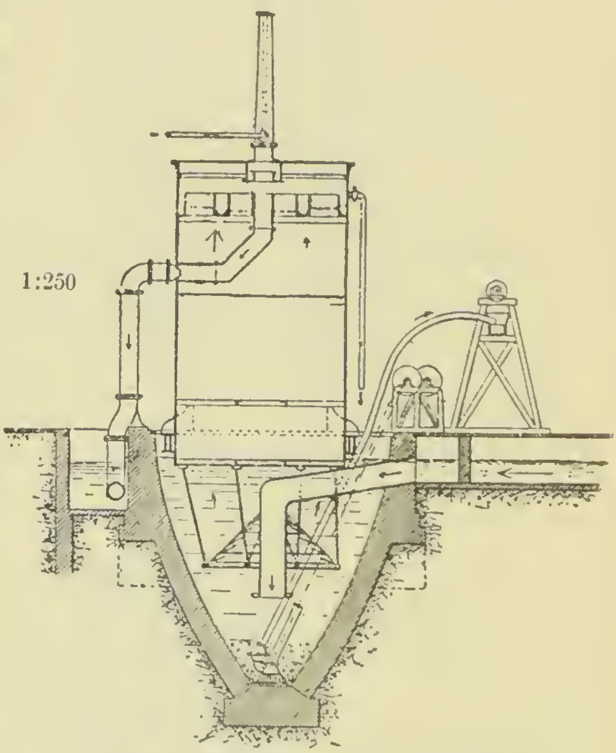


FIG. 137.—UPRIGHT TANKS, ROECKNER-ROTHE SYSTEM.

prevent the injurious effects of changes in the weather. This is expensive, however, as is also the removal of a large stratum of sludge; and on that ground the following system is to be preferred:

3. *Upright Precipitating Tanks.*—One of the leading systems using these tanks is the MUELLER-NAHNSEN, operated in Halle. The plant in this town is designed to treat a daily sewage of 800,000 gals., although at present the quantity is less than a third of this amount. It consists of 2 tanks, Fig. 136, shaped like wells, and provided with a by-pass to be used during repairs or ex-

ceptionally heavy storms. The sewage passes through a sand pit and mixing channel into the tanks by an opening embracing a third of the circumference. It then rises and finally escapes through a number of separate channels into the outfall. During the rise of $9\frac{3}{4}$ ft. the sludge is precipitated and collected in the bottom, whence it is removed by suction pipes. The same process is then gone through with in the second tank, and the finer parts of the precipitate collected, although a single larger tank would probably suffice for the whole operation. In another MUELLER-NAHNSEN plant in Ottensen the bottoms of the tanks are conical, as shown by the dotted lines in Fig. 136, in order to better collect the sludge about the suction pipe. In this plant the inlet and outlet are simply 2 openings diametrically opposite, although not on the same level. This arrangement did not give a good circulation, and in a recent plant in Halle the effluent escapes from around the whole upper rim.

The ROECKNER-ROTHE system was tested experimentally in Essen, and finally permanently adopted. The apparatus, Fig. 137, consists of a conical well, in which the bottom of an iron chamber, or bell, is held by means of suitable beams. The sewage flows into the well through an iron pipe after being mixed with the charge of chemicals. A skeleton frame of iron rods, arranged like an umbrella, causes the sewage to become thoroughly mixed with chemicals before it rises to the top of the bell, whence it flows into an iron outfall pipe leading to an open drain. The motion of the sewage in the bell and outfall pipe is entirely automatic, being due to the slight difference in elevation between the water level in the inlet and outlet drains caused by the friction of the apparatus. In order to start the siphon, a small tube is attached to a pipe at the top of the bell and the air above the water removed by a small air pump. This pump is also operated a short time each day, in order to remove the gas that collects. The particles of sludge are precipitated on the iron frame and at the bottom of the well, where they enter a suction pipe and are thus removed. A small pipe leads from the upper level of the water in the bell to a waste channel, and is used to remove the globules of fatty matter which collect on the surface.

The plan of the Essen plant is shown in Fig. 138, from which it will be seen that the sewage passes through a grating, sand pit, and salmonway before entering the precipitating tanks, 4

in number. The spaces marked y receive the effluent from the grease drains, and the chemicals are added at x. With a maximum daily sewage of 636,000 cu. ft., and all the tanks in operation, the sewage will pass upward through the bells at a velocity of about 0.16 in. a second, and will remain in the tanks about 40 minutes. The average daily flow is only about 459,-000 cu. ft., while the sewage takes 55 minutes to pass through the tanks and has a velocity of only 0.12 in. a second. Experi-

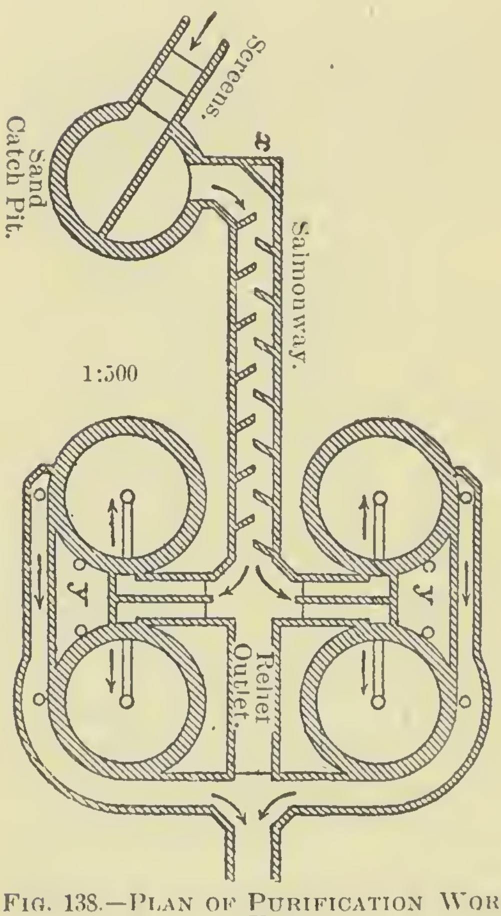


FIG. 138.—PLAN OF PURIFICATION WORKS AT ESSEN.

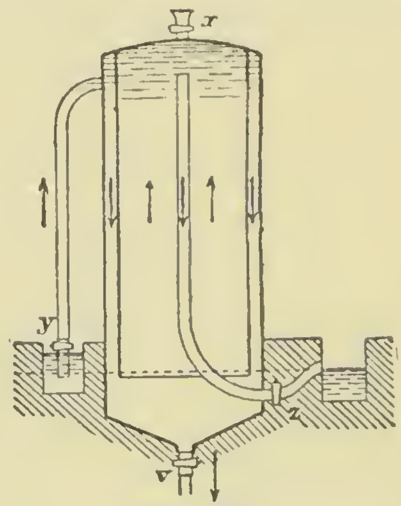


FIG. 139.

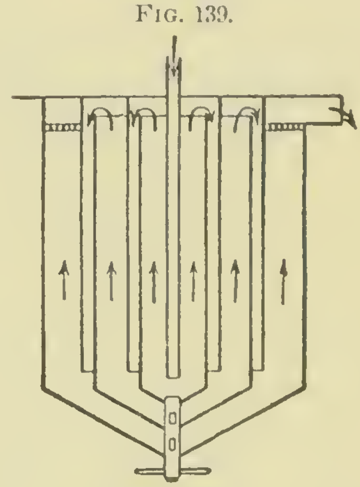


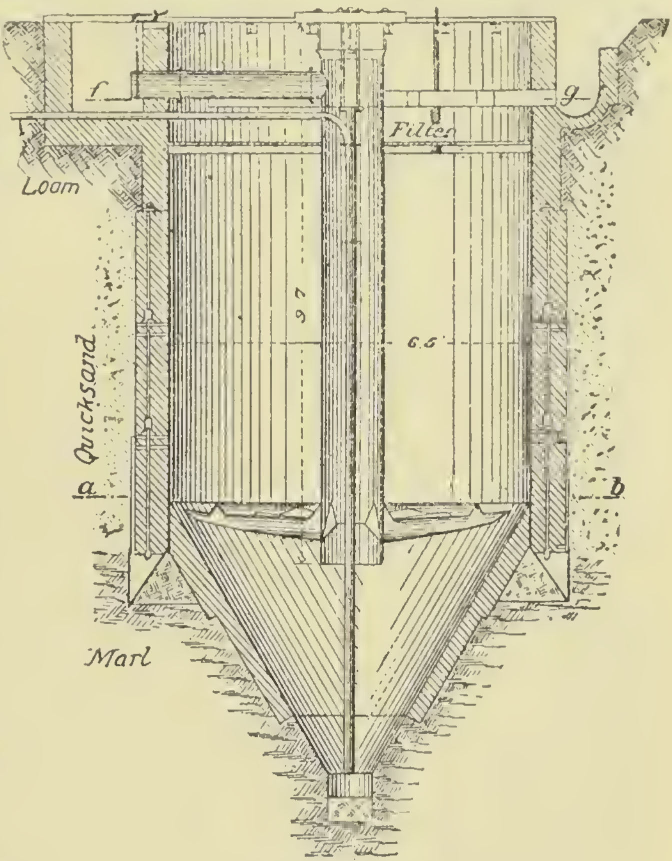
FIG. 140.

ments show that a velocity of 0.23 in. is allowable. On clear days, when the sewage may sink to 423,000 cu. ft., one of the tanks can be cut off and repaired if necessary.

A similar plant is in use in Brunswick, where 2 tanks like those shown in Fig. 137 are employed to treat daily 17,650 cu. ft. of sewage containing excrement. The appliances are of sufficient size to treat 158,900 cu. ft., which will be eventually supplied by the sewerage system under construction. Cologne is also experiment-

ing with a similar plant. The good results so far attained by the apparatus are to be ascribed to the very slow velocity of the current in the tanks and bells.

A siphon may be started by pouring in water, as well as by drawing out air, at its highest point. Advantage has been taken of this fact by SAGASSER in designing the tank shown in Fig. 139. This consists of 2 concentric cylinders and 2 pipes. The apparatus is filled with water by closing the cocks, *y*, *v*, and *z*, and opening *x*. Afterward, when *y* and *z* are again opened, a constant stream flows from the inlet channel, at *y*, to the outfall drain, at *z*. In order to remove the sludge or clean the tanks, *y* and *z* are closed and *x* and *v* opened. Although the



SECTION ON *a-b*. SECTION ON *f-g*.

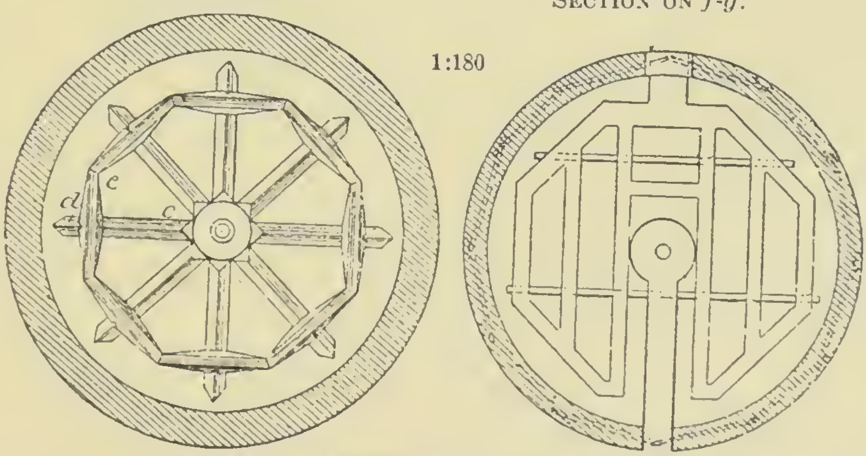


FIG. 141.—PRECIPITATION TANKS, DORTMUND.

apparatus is quite compact, it is possible that with large dimensions the circulation would not be perfectly satisfactory. In this

respect an improved form invented by PICHLER and SEDLACECK, Fig. 140, would probably be more satisfactory, since there are a large number of ascending and descending currents, caused by a series of concentric cylinders closed below by conical bottoms, as shown. The sewage enters and leaves the tank at the top while the sludge escapes through a pipe at the bottom.

The last 2 devices are possibly not suited for the large quantities of sewage which are furnished by cities, but their construction is interesting as containing many points of similarity with one of the latest German precipitation plants, that at Dortmund. This is calculated for a daily maximum of 706,000 cu. ft. during storms, 264,000 cu. ft. during dry weather, and a maximum discharge of 4.6 cu. ft. per second. The average annual flow per second may be assumed to be about 7 cu. ft. Four tanks similar to those shown in Fig. 141 are employed; they are shaped like wells, with a conical bottom, and are driven through quicksand to a firm stratum of marl. The circulation is kept up by hydrostatic pressure alone. The suction sludge pipe passes through an axis of the wheel, as shown. It is surmounted by the inlet pipe and reaches down to the base of the conical portion. The sewage flows from the bottom of this inlet pipe through a set of radiating channels open at the bottom, which insure a good circulation in the tank. Experiments are still being made to determine the most suitable form for these arms. A filter is placed just below the outlet drains, and in this way the light, floating particles are retained. The calculated maximum velocity in the tank is 0.08 in. per second, while the average is fixed at about 0.06 in. As compared with the MUELLER-NAHNSEN system, it is more compact, and there will probably be a more uniform circulation; compared with the ROECKNER-ROTHE system it is less expensive and more simple, although the removal of the sludge offers greater difficulties. The intention is to remove this sludge by means of tight vessels from which the air has been exhausted. On connecting the sludge pipe with one of these, it is hoped that the sludge will be forced into the vessel by atmospheric pressure.

A combination of this system with some of the features of the ROECKNER-ROTHE plan has been proposed but not yet tested. In general, it is safe to say that with our present knowledge the nature of the ground on which the plant is to be built will largely determine the nature of the system to be adopted.

The 3 classes of precipitation works described have not as yet furnished any large amount of data by which their respective merits may be judged. In each of them a suitable quantity of chemicals will produce satisfactory results. In order to compare the cost of treating by the different systems, extensive experiments on equal quantities of the same sewage must be conducted for some time. Theoretically and experimentally, intermittent precipitation offers many advantages on account of the complete rest of sewage in the tanks. Experiments seem to show that this method is preferable to the continuous treatment, however slow it may be. In Bradford it has been noticed that particles settled at the rate of about 2.36 ins. a minute in the intermittent tanks. If there had been the usual current of upright or continuous tanks, little settlement could have taken place. Upright tanks are undoubtedly the most unsuitable in this respect, since the current directly opposes the falling matter, and the tanks themselves are of comparatively small size. Complete quiet and plenty of time are necessary for complete chemical precipitation, and the intermittent treatment seems best adapted to these requirements, especially on financial grounds.

Since the proper method of disposal is to be settled, not only on chemical grounds, but also with reference to local conditions and cost of plant, the following facts must be borne in mind: 1. Level tanks for intermittent precipitation require much space and a considerable difference in elevation between inlet and outlet channels. 2. Level tanks, with continuous precipitation, also occupy considerable space, but do not require any grade within the plant. 3. Upright tanks require little room or grade. The latter are therefore to be preferred within city limits, where the cost of the land is considerable. The first class are unsuited for cities with a level surface, since the pumping that would be necessary is expensive.

The regular and practically continuous removal of the sludge in the upright tanks necessitates but little space in which it may collect, and insures a freedom from the injurious effects upon the effluent which long-standing deposits may cause. The sludge is also better adapted for handling while in a fresh condition. The intermittent tanks come next in this respect, especially if they are cleaned every day. The continuous tanks rank last as regards the treatment of the sludge, which, in them, is liable to decay, become offensive, and injure the purity of the effluent.

CHAPTER IV.

Results and Cost of Purification.

The results of purification are to be determined by the appearance of the effluent, by chemical analyses, and by examinations of the bacteria; all three methods are necessary to arrive at a correct decision, and any one, by itself, may lead to wrong conclusions. The effluent may be clear and free from disease germs, but contain dissolved matter which is subject to change as soon as new bacteria are absorbed from the air. On the other hand, a turbid effluent may be harmless so long as none of the matter decays, and a chemically pure water swarming with bacteria may have no bad properties as long as the animalculæ are of an innocuous character.

A great number of chemical and microscopical investigations have been made of both ordinary and purified river water in the English and German places where purification has been tested or adopted. The mass of data thus given is of little value in obtaining a clear idea of the actual advantages of the different methods and apparatus for purification, since climatic, local, and other attendant influences are so varied. On that account only a general summary of the results will be given.

English experiments show that in simple mechanical precipitation, from 60 to 80 per cent. of the suspended matter, organic and inorganic, is thrown down. Where a preliminary purification is conducted by gratings and the sewage remains some time in large basins, as in Frankfurt, the results are better and even equal to those obtained by chemical means. There may be some quite light organic matter in the sewage, and this will only be precipitated by adding chemicals. In general, from 75 to 100 per cent. of the suspended matter may be precipitated by both processes; where this is not the case, either the time of settling or the chemical action is too weak.

Of dissolved matter, from 30 to 60 per cent., both organic and inorganic, may be precipitated by chemical treatment. But it is not unusual to meet with an increase of both classes, and the

sewage will sometimes contain, after the addition of chemicals, 25 per cent. more matter liable to decay than originally. This may be partly owing to the excess of lime in the charge having caused some of the suspended matter to become dissolved, and partly to the decay of the precipitated sludge. An increase in the amount of dissolved inorganic matter is of little consequence, and indeed is welcome, up to a certain degree, when due to lime, which is a disinfectant. The clarifying material used up to the present time is not able to work surely on all the dissolved matter. A reagent for ammonia is specially needed, for the best methods now in vogue will only act upon about 20 per cent. of the quantity present. The dissolved potash also remains unaffected, which is not of consequence so long as the water-course itself, into which the effluent flows, contains mineral matter. Phosphoric acid is almost entirely removed, and the nitrogen is reduced about a third in quantity, occasionally as much as 60 per cent. The experiments in Frankfurt apparently show that by using large settling tanks, especially long ones, almost as good results may be obtained by mechanical means as by chemical treatment in smaller tanks.

The bacteria are naturally only affected by chemical precipitation.* In this way the greater part may be removed; in Wiesbaden 70 per cent., in other places as high as 90 per cent., and there is no doubt that all can be eliminated with a sufficient charge of chemicals and enough time for complete precipitation. According to KOCH and investigations in Cologne, lime is the only disinfectant; while in other places this material has not given so good results. Experiment shows that both sludge and effluent are purified, and both remain free from germs so long as free lime is present. It is a question, however, how long the development of bacteria is hindered by this means, since the lime absorbs carbonic dioxide from the air and changes to calcium carbonate. Moreover, the combinations of lime and fatty acids are not stable, and the lime in them also changes into a carbonate. The organic matter set free is liable to subsequent fermentation, both in the water and in the sludge, by absorbing bacteria from the air. If this could be prevented until the effluent enters the water-course, all requirements would be fulfilled, since the dilution then brought about would reduce the action of the bacteria, and the resulting products would be widely scattered.

* Simple sedimentation will undoubtedly carry down many bacteria.

If a charge of chemicals sufficient to kill all bacteria were added, then the purpose of sewage purification, *i. e.*, the preservation of the harmless character of water-courses, would not be fulfilled, since the chemicals added would practically poison the water, besides greatly increasing the expense of the treatment. On this account the addition of strong disinfectants, such as carbolic acid, zinc chloride, copper sulphate, or large quantities of quicklime, is by no means to be recommended. In short, it is only a best possible, not ideal best, method which should be sought out.

Looking at the matter from this standpoint, which is that of the German Association for Public Sanitation, many persons claim that sewage is sufficiently purified when it appears clear to the eye,—at the outside, when the bacteria are destroyed,—and maintain that the precipitation of dissolved matter is not necessary, since it is never complete and is less important. The clarification, which insures subsequent freedom from sediment, hardly requires the use of chemicals for ordinary sewage, but may usually be obtained by careful mechanical treatment. Chemicals are necessary to destroy the bacteria. Among those now in use, the cheapest, lime, is fortunately the best and possibly the only substance. Since the mechanical and chemical treatments are carried out in the same way, it is possible to use the former during the ordinary condition of the sewage and water-course, reserving the latter for unusual occasions, such as low water or epidemics. The presence of factory sewage, or some similar outside addition to domestic sewage, may render the constant use of chemicals necessary, and the sludge may also require such an addition.

The sludge in settling tanks must be sufficiently wet to be removed by suction pipes, since a firmer consistency greatly increases the cost of handling. Generally, in flat basins about 90 per cent. of water and 10 per cent. of solids will be a good proportion, while in upright tanks sludge with only 65 to 80 per cent. of water can be pumped away. From the quantity of chemicals and suspended matter it is easy to calculate the theoretical amount of sludge which will be precipitated, but such calculations are not sure. English investigations show that from every gallon of sewage containing excrement about 2.3 cu. ins. of sludge will be deposited in the above liquid condition, while in Essen only 0.9 cu. in. is precipitated from the sewage without excrement. The proper

size of intermittent settling tanks can be easily calculated. Suppose, for instance, the tank shown in Fig. 128 requires 3 hours to be filled, and 3 days elapse between the successive removals of the sludge. Let there be a capacity of 8,829 cu. ft. above the outlet. Then the sludge basin must have a capacity of $24 \times 8,829 \times 00.01 = 2,119$ cu. ft. if the sewage deposits 1 per cent. of solid matter. The sludge may or may not have a disagreeable odor, depending largely on the nature of the process used. It is certainly possible by suitable chemicals to have a practically odorless sediment, as the Roeckner-Rothe process has shown, but it is not always best to go to extra expense for such a purpose. Generally the sludge has an extremely offensive odor, which is dissipated but slowly.

The sludge is disposed of by numerous methods, and a choice between them is to be made according to local circumstances. They may be divided as follows :

1. Removal from the settling or receiving tanks by pumps or pneumatic methods to vats in which the sludge is carried to the fields for fertilizing purposes.

2. Deposition in sludge basins $1\frac{1}{2}$ to 5 ft. deep, formed by puddled or masonry walls, and suitably drained. The sludge flows into these generally through open channels, and loses by evaporation and drainage in 1 week 30 per cent., in 3 weeks 50 per cent. of its water, becomes firm, and has only a slight odor Finally it is removed to fields.

3. Drying on loose soil, and then plowing, as soon as possible, into the ground where it lies.

4. Removal of the water either mechanically or by a gravel filter.

5. Concentration by a filter-press until 50 per cent. of the water has escaped ; the product used as a fertilizer.

6. Removal of 80 to 90 per cent. of the water by a vacuum process or by evaporation, leaving a powder.

7. Reduction to a powder, as in 6, but with the addition of ground bone, ammonium sulphate, or a similar substance, in order to obtain a better fertilizer.

8. Burning in a suitable furnace after a preliminary drying. The ashes are fertilizing in character.

9. Mixing the sludge of the lime process with clay to form cement ; the Scott process.

10. Mixing with clay to form bricks, which are of very ordinary quality when lime precipitation has been employed.

11. Mixing with combustible, and if possible disinfecting substances to form briquettes for burning. Peat, tan bark, and tar are suitable additions.

12. Mixing the partially dried sludge with earth and rubbish to form compost heaps. Vegetable mold, marl, gypsum, and sweepings may be used. Since the house and street sweepings have a greater bulk than the sludge from sewage, the treatment of the latter is a subordinate and easy matter as long as there are suitable regulations governing the disposal of the rubbish of a city. In this process the presence of lime in the sludge is advantageous.

The simple agricultural disposal of the sludge by methods 1, 2, 3, and 12 offers many advantages. The third method is especially economical on account of the absence of transporation expenses, since the sludge runs directly to the fields and into a ditch, which will subsequently be covered by the earth taken from a parallel one during its excavation. The land may receive in this way a deposit of sludge sufficient to raise it 1½ ft. After it has stood a year it may be used for raising crops, which will be benefited by the fertilizing sludge. The number of years that must elapse before a second layer may be added depends upon the agricultural use of the land; generally 3 will suffice. The gradual increase in elevation of the land is an unavoidable evil, and may be insurmountable in a flat locality.

The method mentioned under 1 requires no special plant, while 2 and 3 require but a moderate area. The methods 1 and 12 are commendable on account of the decrease in odor, the great nuisance of sludge disposal.

Although a continuous removal of sludge is greatly to be desired, it is opposed by the fact that the fields require fertilizing, or are even fit to receive the matter during certain seasons only. Hence a very undesirable accumulation of sludge is formed, which may be avoided by the fifth method, and several secondary advantages obtained at the same time. A filter-press will require but little space, and produces a marketable briquette, possessing little odor and easily handled.

The theoretical value of sewage sludge as a fertilizer is not great, since only a part of the organic matter is precipitated. The following table gives a summary of series of determinations of sewage sludge containing excrement from several English cities

and from Frankfurt. The sludge from English cities was obtained by the lime process, while that of Frankfurt was taken from the settling basins already described :

COMPOSITION OF SEWAGE, IN PER CENT.

	England.		Frankfurt.	
	Dry.	Fluid.	Dry.	Fluid.
Water	7-15	90	......	91-94
Organic matter	20-40	2.2-4	45-57	3.7-4.2
Nitrogen	0.5-1.5	0.05-0.16	3.3	0.2-0.3

The sludge from other German purification works, into which a part of the excrement enters, has been repeatedly analyzed. In a dry condition it contains from 17 to 37 per cent. organic matter, 0.7–1.5 per cent. nitrogen, and 0.8–2.5 per cent. phosphoric acid. The presence of lime is unnecessary, except where the soil to be fertilized is very poor.

Theoretical calculations of the value of the sludge are of no significance, since the relations of supply and demand decide that subject, and the actual net proceeds are very different in the various plants. In several purification works the accumulation of heaps of sludge has caused much trouble, and in the majority of cases the directors are usually glad to have the sludge itself, or even the products made from it, removed without cost to themselves. In Wiesbaden, Essen, and Frankfurt the municipal authorities have begun to use it on the public property, in order to encourage private parties. In Dortmund the sludge, treated by the second method and containing some lime, is sold at from 12 to 19 cts. per cu. yd., being valuable as a fertilizer on account of the extremely poor soil in the vicinity. In Halle, where the fifth method of treatment is employed, the sludge containing about 50 per cent. of water, is worth about 50 cts. a ton at the works.

In chemical clarification the precipitants form the chief item of expense. Since the amount of these varies considerably and is not to be determined beforehand with any accuracy, it is best to base the calculations on the quantity of carrying water and a certain fraction of the annual rainfall, which under favorable circum-

stances, such as concentrated rains and numerous relief outlets, may reduce to almost nothing.

From data running back for several years, obtained by examining the records of 7 English plants, it is possible to form some idea of the operating expenses of such works. It has been found that it costs from 47 cts. to $1.70 to treat 100,000 galls. of the total sewage, some of which is not, however, actually passed through the works. This corresponds to from 10 to 35 cts. per capita annually. If these figures are increased by an amount corresponding to the interest and depreciation on the plant, they become 94 cts. to $2.35, 17 to 45 cts., respectively. The Coventry process has been the most expensive.

TABLE VIII.—APPROXIMATE COST OF CHEMICAL PRECIPITATION IN GERMANY.

	Frankfurt.	Wiesbaden.	Halle.	Essen.
No. of residents which the plants serve	150,000	60,000	10,000	68,000
Cost of plant, total $	187,500	50,000	8,700	57,000
Ditto, per capita $	1.25	0.83	0.88	0.83
Annual running expenses $	35,000	8,250	1,650	7,250
Ditto, per capita $	0.24	0.14	0.16	0.11
Ditto, including interest $	0.31	0.19	0.22	0.16
Average daily sewage cu. ft.	950,000	22,900	31,700	457,000
Ditto, per capita cu. ft.	6.3	3.9	0.3	6.7
Running expenses, per 100 cu. ft., cts	1.0	1.0	1.4	0.4
Ditto, including interest cts.	1.3	1.3	1.8	0.6

Some of the experimental results obtained in German cities are interesting. In the ROECKNER-ROTHE apparatus tested at Essen the separate items of cost for treating 100 cu. ft. of sewage were: Chemicals, 0.7 ct.; labor and power, 0.5 ct.; interest and repairs, 0.2 ct.; total, 1.4 cts. The operating expenses of the MUELLER-NAHNSEN system in Halle were variously stated to be from 1.8 to 3.8 cts. per 100 cu. ft, of which amount about 2.1 cts. represent the cost of the chemicals. The price received from the sludge, 0.1 or 0.2 ct., must be deducted, and 0.4 ct. added for interest.

In the comparative table above, it is to be noted that $20,000 of the Frankfurt expenditure was paid for land, and $35,000 in Wiesbaden went for a mill for supplying power.

The small expense for operating in Essen is due to the extremely diluted condition of the sewage and the absence of excrement, found in the sewage of the other three cities. In other cases, the ROECKNER-ROTHE system may be dearer; in Bruns-

wick, for example, the annual operating expenses for each resident are 40 cts. and 3 cts. per 100 cu. ft. Since German experiments in this direction are still very few, it is to be hoped that more extended data will be found to give diminished expenses. The experiments so far made public give no means for deciding upon the relative value of the different systems now in the market.

CHAPTER V.

Aëration.

Since it is not possible to remove by precipitation more than a small part of the organic matter dissolved in water, a process by which nearly all could be removed after the water was otherwise purified would be welcome. This may be accomplished by forcing currents of air into the stream. The more oxygen there is present in the water the greater will be the reduction of the organic substances to carbonic dioxide and other compounds by the bacteria, as already explained in the chapter on the self-purification of rivers.

This aëration may be accomplished in several ways. Merely forcing currents of air against the surface of water has not been successful. Better results are obtained by agitating the water by hand, or with revolving wheels provided with floats or arms, but such methods are not possible with large quantities. The air may be blown into the water through a number of openings in a pipe, either by a blowing engine or an injector, Fig. 127. Koerting has proposed an automatic aërator through which the water flows and absorbs air by its own motion; compare Fig. 184. The best plan with large quantities would probably be to separate the whole mass into as fine subdivisions as possible. In several English cities the effluent from the purification works flows in extremely shallow streams over weirs; in Sheffield the surface of the effluent spillway is 904 sq. ft. The same end can be accomplished by large sieves, which have been used in the precipitation works designed by Professor Koenig at the starch-factories in Salzuflen, where the average daily effluent is 52,900 cu. ft. The apparatus has been installed for experimental purposes, and its continued use or improvement will depend upon the results attained. The water is allowed to escape along the entire length of a wooden channel to a wire sieve having an undulating surface. Professor Koenig's investigations with this apparatus show that the decaying and other organic matter is oxidized, especially the sulphurous acid into sulphuric acid, and the sewage is mixed with a large

amount of oxygen, which may rise to eight times the original contents, and continue the reduction after the effluent enters the river. Other investigations have shown that the oxygen in the water gradually disappears, while the carbonic acid proportionally increases. It is said that ammonia will sometimes be directly oxidized without the presence of bacteria in certain cases. It is important to remember that the aëration of *turbid* water will only have a temporary deodorizing effect, and the process should therefore be only used after the sewage has been clarified.

It has been already noted that, in sludge precipitated with an excess of lime, carbonate of lime will be found. An increase in the quantity of inorganic sludge will also tend to increase the organic deposits. Hence the addition of carbon dioxide would be advantageous in some cases. KOENIG has employed furnace smoke for this purpose, and the experiment has been successful in the main in precipitating both lime and organic matter. The smoke contains not only carbon dioxide, but also small quantities of oxygen and distillation products containing creosote compounds, which check decay.

The aëration of sewage by sieves requires a difference in elevation that may necessitate pumping, which is necessary in all the other processes for the same purpose. Whether the resulting expenditure is warranted is still undecided.

CHAPTER VI.

Filtration.

The sewage of a city is often purified by the process of intermittent filtration, in which it is distributed over the upper surface of the ground, passes through from $4\frac{1}{2}$ to 6 ft. of filtering material, and finally flows away through a network of subsoil drains. The filter-bed may consist of earth, sand, clay, pieces of brick, coke, or fine quarry chips. The beds may be only 2 ft. thick in some cases, and the sewage may be forced upward or horizontally through the material. The action of a filter is due partly to a simple mechanical retention of the floating matter, and partly to the oxidation of organic matter by oxygen contained in the interstices of the material, aided by bacteria. The results of the process, especially with earth filters, are very variable. Beside the climatic conditions, the following influences are to be noted:

Permeability to Air, preventing decay, insuring oxidation, and allowing carbonic dioxide, a disassociation product from the organic matter, to escape. With plenty of air the proper bacteria will be found, while without it those attending putrefaction will be present. According to old English experiments a quantity of sewage not exceeding $2\frac{1}{2}$ to $6\frac{1}{4}$ per cent. of the volume of the filter bed should pass through it in 24 hours; Frankland, after comparing results from a large number of plants, says 2 to 4 per cent. The beds should rest about 3 hours for every 1 of filtration, in order to absorb oxygen from the air. They should also be occasionally cleaned and the upper layers renewed.

Permeability to Water.—The filtering material must be insoluble, easily dried, and allow a good circulation of the water. The filtration may be too quick, however, to permit the removal of any appreciable amount of the dissolved organic matter, as during heavy rains or through coarse gravel. The duration of the process in heavy ground may be fifty times that in more porous soil.

Absorbing Power.—The beds should retain the dissolved organic matter, especially ammonia, but allow the nitrates, resulting from

the oxidation of such compounds, to be washed away. This process is at the basis of water purification by filtration, especially by charcoal filtration.

Pressure on Filter-bed.—If a deep body of water covers the filter-bed, the effluent will be diminished by the choking of the interstices with sludge, in spite of the advantage of a large hydrostatic pressure. Experiments with a sand-filter in Berlin showed that the effluent under a pressure of 3.27 ft. was from 0.23 to 0.65 cu. ft. per day per square foot of filtering area. Under a pressure of 1 ft. the effluent was from 1.35 to 3.05 cu. ft.

Subsoil Water.—Its presence, either from the low position of the land or by capillary action, prevents aëration, and tends to breed the bad species of bacteria. The drainage of a filter-bed should be directed, therefore, to subsoil water as well as sewage.

With proper management, all of the suspended and from 70 to 90 per cent. of the dissolved organic matter may be removed. The inorganic matter, on the contrary, will be increased by various carbonates and nitrates. Chlorine passes unchanged through the filter, while from 50 to 90 per cent. of the nitrogen will be removed. The animalculæ disappear with the organic matter on which they subsist.

From the above data it is easy to calculate the dimensions of a filtration plant, but it is generally more safe to make direct experiments in each case. In seven English cities an acre of filtering area is allowed for from 400 to 2,800 inhabitants; in other words, 1 acre will suffice for from 2,150,000 to 3,580,000 cu. ft. annually.

If an attempt is made to diminish the area of such beds by increasing the amount of sewage passing through them, the result is bad, owing to the fact that only the suspended matter will be removed, while the dissolved passes through unaltered or partly converted into ammonia. If the periods of rest are not long enough the same results follow. Other difficulties attending filtration consist of the depreciation in value of the sewage as a fertilizer, and the trouble of disposing of the saturated layers of the beds when removed after long use. The use of the land for raising crops only partly remedies these evils.

For the above reasons the filtration process has been often given up after trial, especially in England, where it has been much favored. It is now employed in few places, only where an excel-

lent porous soil can be found which is not of sufficient area for irrigation. In a few such plants, other lands in the neighborhood are occasionally allowed to be used as filter beds, while in still other places the beds are used as adjuncts to irrigation fields, in order to be able to treat unusually large quantities of sewage if required. The area considered necessary for intermittent filtration is gradually increasing, and it will soon be somewhat difficult to draw a line of demarcation between filtration and irrigation. The leading English advocate of the system now recommends 1 acre of filter beds for 1,010 inhabitants with the best, and 210 inhabitants with the worst, class of ground. BUERKLI bases his calculations on 1,400,000 cu. ft. of sewage per acre annually, and designs his plant in such a manner that each bed is used every third year for intermittent filtration, and is worked as an irrigation field during the other years.

The difficulties mentioned above have often led to a preliminary chemical treatment of the crude sewage before it is run through the filters. When the greater part of the suspended matter has been removed, the pores of the ground become less frequently choked, the odor is not so offensive, and the filter beds may be of reduced extent. Their thickness is sometimes only from 1.9 to 3.3 ft., but generally from 4.9 to 5.9 ft., and an English empirical rule for their size is to make them equal to half the volume of crude sewage treated. Intermittent filtration, with 3 hours rest to 1 of action, is the process employed in such cases.

In several places river water is filtered through sand for the purpose of obtaining a water supply. In such cases the beds are from $3\frac{1}{4}$ to $6\frac{1}{6}$ ft. thick and deliver from 0.33 to 0.59 cu. ft. daily from each square foot of area. The period of rest is generally short. Since sewage is not so pure as river water, and the pores of a sewage filter must contain a greater amount of oxygen than a water filter in order that the necessary chemical changes may take place, it may be approximately assumed that the area of the former class should be from two to three times that of the latter.

The results of combined precipitation and filtration depend naturally upon the duration of the process and size of the plant. Since the latter is usually as small as possible in order to reduce the expenditure for land, it is not surprising that the effluent is generally inferior to that from filtration proper alone. In Birming-

ham about 30 per cent. of dissolved organic matter was removed by lime precipitation and 34 per cent. by a subsequent filtration, while direct filtration, properly conducted, removes from 80 to 90 per cent., as already stated. A considerable area is always necessary to obtain good results, and the relative cost of land, chemicals, and other items of expenditure govern the employment of preliminary precipitation.

The sewage might be made to first pass through filters and afterward be treated chemically, a more rational order, since the mechanical process would remove the greater part of the suspended matter, and the charge of chemicals necessary to precipitate the dissolved substances would be diminished. The removal of the sludge would be easier, although the filter would collect a relatively greater amount of matter. Fortunately the latter drawback can be diminished by using horizontal filters, such as have been employed for some years in English cities. Fig. 142 shows the arrangement adopted at Coventry, where masses of sand, held by boards, are used.

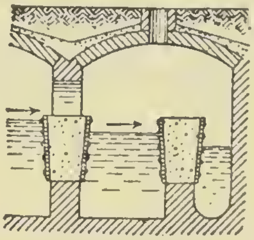


FIG. 142.—FILTERS AT COVENTRY. 1:250

Dr. PETRI has employed this principle in the purification plant of the prison at Ploetzensee, near Berlin, where 3,500 cu. ft. of domestic sewage are treated daily. The results cannot be definitely stated as yet. A peculiarity of this plant is the use of peat as a filter, which acts not only mechanically, but also as an antiseptic, reducing the amount of chemicals necessary in the charge.

The operation of the plant can be easily understood from the diagram shown in Fig. 143. The sewage flows from the channel *a* into a series of tanks, *b*, where the preliminary filters of peat are placed. The peat is arranged between walls in such a manner that sections of it may be replaced without interrupting the process. The sewage flows from these chambers into a collecting channel, *c*, which empties into a mixing tank, *d*, where the charge of chemicals is added. PETRI has recommended various chemicals, the latest being a mixture of 20 grains of lime and 3 grains of magnesium sulphate to each gallon of sewage.

The precipitation or settling basin is at *e*, through which the sewage constantly flows. Water weeds are allowed to grow here in order to aid in oxidation, as mentioned in the chapter on the self-

purification of rivers. The sewage then passes through a channel, *f*, filter, *g*, and channel, *h*, arranged like *a*, *b*, and *c*, into a final filter, *i*, composed of gravel or coke. The peat in *g* contains lumps of limestone for absorbing the sulphate of alumina, which might otherwise enter and poison the river. The effluent is thus actually clarified.

A grating is placed over the filters, as shown by the dotted line at *b*. On this rests a thin layer of peat sprinkled with carbolic acid, to counteract the offensive vapors given off by the matter retained in the filters. Whether such an arrangement is necessary depends naturally on the local circumstances.

The dimensions of the plant at Ploetzensee, the only one now in use, are as follows: Average depth of water in *a*, 1.2 ft.; length of filter from slope to wall, 10.5 ft; rate of filtration, horizontally,

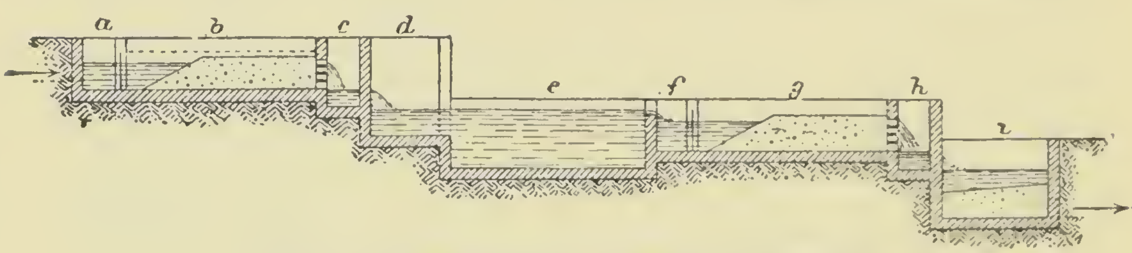


FIG. 143.—PRECIPITATION TANKS, PETRI SYSTEM.

from 0.13 to 0.22 in. a second. Hence each square foot of vertical cross-section delivers about 6 cu. ft. of effluent an hour, much more; owing to the porous peat, than the results with an ordinary sand filter and river water. Moreover, the peat becomes choked less rapidly and requires less aëration. In actual practice the surface is occasionally raked over during the day, and the slope of the filter renewed. Otherwise there is no labor necessary, except a renewal of the peat every 20 or 30 days, when the effluent begins to be turbid. The maximum flow of sewage only occurs a short time each day, and the peat is sufficiently ventilated during the remainder of the 24 hours.

The second filter has only three-fourths the sectional area of the first, and remains in good condition three times as long. The quantity of chemicals employed for each gallon of sewage may be reduced from that already given in the chapter on chemical precipitation on account of the diminished duty demanded in this part of the process.

Chemical analyses show that not only the suspended, but also

the dissolved, organic matter is almost entirely removed, and of the inorganic matter only 20 per cent., mainly lime and chlorine compounds, remains in the effluent. Extensive experiments must be made before the best dimensions and methods of working are determined. The cost of operating still remains to be ascertained. Knauff estimates it at about from 10 to 18 cts. per capita annually, or from 0.7 to 1.4 ct. per 100 cu. ft. of domestic sewage, depending largely on the ease with which peat can be obtained. This estimate assumes that the filtering material and sludge may be easily removed and the former employed as a fertilizer or fuel. The ability of such a process to treat large quantities of sewage still remains to be demonstrated, as well as its financial relation to other methods.

CHAPTER VII.

Irrigation.

Irrigation with sewage on a large scale is a comparatively new branch of agriculture, not yet adapted for all places, and with defects which may be overcome later on. The term "irrigation," when used in connection with sewage, covers a much wider range of problems than the simple watering of a meadow or plain, which is its usual signification. The different plans for disposing of the sewage are as follows:

1. *Surface Irrigation.*—This plan consists in leading the sewage to a long channel, having a square cross-section of about 1 ft., and running along a ridge from which the land slopes away at a grade of one or more per cent. The sewage flows over the edge of this channel along its whole length, and is prevented from collecting in little streams on the slope by a series of shallow ditches running parallel to the main channel and from 35 to 50 ft. apart. Where there are extensive fields to be irrigated in this way, the land is subdivided into areas from 650 to 1,160 ft. long and 200 to 230 ft. wide, down the center of which runs a channel from which the sewage escapes on both sides.

2. *Bed Irrigation.*—In this system the land is subdivided into a number of beds 3 ft. wide and 65 to 100 ft. long by ditches about a foot wide. The sewage passes through the network of ditches and is absorbed by the beds. The sludge that collects in the ditches is occasionally removed and dug into the lands. Before planting it is possible to overflow the beds according to the next method.

3. *System of Flooding.*—In this method of irrigation it is customary to flood the land with from 10 to 20 ins. of sewage by means of earth walls about 3 ft. high. The liquid part of the sewage percolates through the ground and escapes, leaving the fertilizing portions on the surface. Sometimes the water is allowed to flow away over the surface, while at other times, especially in winter, the process is repeated until a deposit of sludge as thick as 8 ins. may be formed. Low plants are started after the

flooding, while shrubs and trees may be set out at any time, since the presence of the sewage has little effect upon them. It is best to give fields managed in this way for cereal crops a considerable area ; from 5 to 22 acres have been thus treated in single fields in Berlin.

4. *Gerson's System.*—GERSON conducts the sewage to the fields in cast-iron pipes placed below the frost line and about 1,300 ft. apart. These pipes have hydrants every 650 ft. or so, from which the sewage can be discharged, through a galvanized-iron pipe line 4 to 7 ins. in diameter, over the surrounding land. By means of a plow a series of low, temporary walls can be easily formed, between which the sewage is allowed to settle. Various modifications of the general plan are made to suit the requirements of the different seasons and crops. The advantage of the system lies in the fact that the land is not divided by fixed boundaries.

5. *Subsoil Irrigation.*—This plan consists in conducting the sewage through a brick or cement delivery sewer, from which it passes into a network of tile pipes underlying the whole field. The sewage escapes from the joints of the pipes, usually of 2-in. tile, from 8 to 16 ins. below the surface and 3 to 6½ ft. apart. Semi-cylindrical covers over the top of the pipes will prevent their clogging by dirt. The grades should not exceed one per cent., in order that the sewage may be uniformly distributed over the entire area.

In all cases it is necessary to provide two sets of pipes, one for the sewage and one for the effluent. Each is a separate network, and may be partly on the surface and partly below it. The sewage pipes must be higher than the others, and it is therefore occasionally necessary to make artificial slopes. The distance between the sewage and effluent systems should be so chosen that the sewage flows evenly and with sufficient velocity to prevent any accumulations detrimental to the crops. In general the greater the slope the greater may be the distance between the delivery and discharge ditches.

Starting out from the pipe lines through which the sewage is pumped to the irrigation fields, as in Danzig, Berlin, Breslau, and other places, or the simple gravity ditches, similar to those employed in Freiburg, are the series of underground or surface pipes which lead to all parts of the field, gradually decreasing in size toward

the outer ends. Suitable arrangements of flash boards and gates control the distribution of the sewage, and facilities for regulating the total quantity delivered to a field should always be provided. In addition to a telegraphic communication with the pumping stations, it is often customary to erect small stand-pipes at the end of the pipe line or highest point of the ditches. These stand-pipes are usually about 20 ins. in diameter and 33 ft. high, provided with a float carrying a flag or other signal by which the condition of the supply can be easily seen at a glance. The tops of these stand-pipes end or connect with a small reservoir, where any overflow may be collected. The effluent is collected by ditches or pipe drains, the choice being governed primarily by the nature of the soil, and in a less degree by the relative cost of construction of the two systems. The drains are from 4 to 6½ ft. below the surface, although in the very sandy soil of Berlin they are only a trifle over 3 ft. deep.

The action of an irrigation field is threefold: *a.* The sewage is mechanically filtered and the suspended matter thus separated. *b.* The dissolved organic matter is also removed by oxidation in the presence of bacteria, and ammonia and minute quantities of nitric and sulphuric acids given off. *c.* The plants absorb the fertilizing substances, especially the dissolved organic matter, and, in a lesser degree, the products of disassociation of the preceding processes. The first and second methods of action are similar to those of filtration beds. They are more complex, however, and more subject to the influence of changes in the weather. In order that the whole process may be successful, certain conditions must be fulfilled. They relate to the following matters:

1. *Nature of the Ground.*—The same rules govern the selection of fields for irrigation as for filtration. A fairly sandy soil is the best. With such ground the sewage should flow in small quantities, but at frequent intervals. With heavy loam the sewage is rapidly absorbed, but given off very slowly. In order to have considerable absorbing capacity, it is desirable that there be a quantity of vegetable mold in the earth.

The heavier the ground the greater the extent of land necessary, since the oxidation will cease nearer the surface. With a too loose soil the sewage flows off before giving up all its fertilizing matter, and on that account the land should be terraced and the effluent from one level run over the next lower one. Where this

is not possible, gates may be placed in the main effluent channel and the sewage held back at different places until it has a sufficient head to be discharged over the land in the vicinity.

2. *Nature of Plants.*—It is desirable that the plants raised on irrigation fields should take up all the matter deposited from the sewage directly, if possible, and after disassociation in any case. This is an ideal condition, however, and it remains to choose such plants as most nearly conform with the composition of the deposited substances. Some ingredients, especially when the sewage contains the waste products from industrial establishments, will always remain unchanged in the soil and be gradually washed away. The variable quantity of sewage and the different agricultural demands during the year render any exact adaptation of crops to the sewage impossible.

About 1 per cent. of ammonia, 0.4 of potash, and 0.4 of phosphoric acid are present in manure, and the same relation between the three substances is also found in sewage. These proportions are not adapted for plants on account of the large quantity of nitrogen in the ammonia. The leaves of a plant demand the nitrogen, the fruit the other ingredients. Hence grass, "greens," turnips, shrubs, and the like give the best crops. Only 15 to 25 per cent. of the fertilizing value of the sewage can be used, according to Knauff. A change of crops is advisable in order that as many as possible of the substances added by the sewage to the fields may be absorbed. The plants should also be so selected that they will allow the air and sunlight to act readily on the earth.

3. *Character of the Sewage.*—The suspended matter has no special fertilizing value in a crude state, and is useful only after disassociation into soluble substances, while it may form an injurious slime on the fields or stop the drains. Whether this disadvantage outweighs its fertilizing value depends upon the method of irrigation. Where drains may be clogged or the level of the ground raised to an extent that hinders the process, the suspended matter is usually removed by a sand-pit, occasionally by a settling tank on the fields. Chemical precipitation has been occasionally adopted, its cost being met by the saving in the labor necessary to remove the sludge or slime from the fields and keep the drains open. Since the dissolved matter is valuable, it is only necessary to employ chemicals enough to precipitate the suspended sub-

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stances. Where all the organic matter is used and is plowed into the land, it is sometimes well to employ mechanical agitators to prevent any settlement in the tanks and ditches. Such a plan has been pursued at Ploetzensee.

Care must be taken that the sewage is not too concentrated, for if a large amount of soluble matter is present the chemical processes of disassociation and combination are rendered difficult and all the substances will not be removed from the effluent. The necessary dilution may be affected by the addition of water from neighboring brooks or ponds, or by running the effluent over the fields a second time. The same means may be employed to furnish the fields with sufficient water during dry seasons.

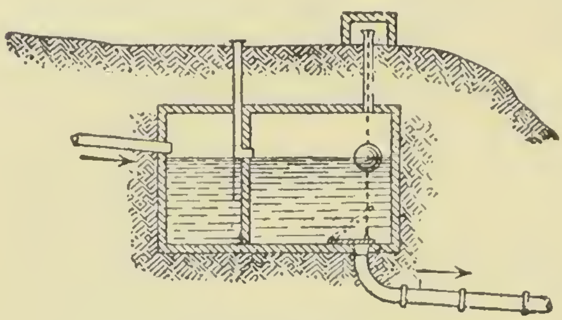

FIG. 144

4. *Management.* — With every irrigation field a good aëration of the ground is a fundamental necessity, and in this respect the different methods outlined above vary considerably. With overflowed fields there is of course no circulation of the air either with slow or rapid percolation. In such cases simply mechanical filtration takes place, the chemical action is incomplete, and it is important to subject the effluent from these fields to a further purification in other places. With underground irrigation, the purification is also incomplete, since the air necessary for oxidation must penetrate a stratum of earth before coming in contact with the sewage.

Bed irrigation is more favorable, but the best plan is surface irrigation worked intermittently. Small areas may be easily cultivated by the distributing and settling tank shown in Fig. 144, in which the sewage is collected, settled, and delivered, either by hand or automatically by a float, when the water-level in the tank has risen to a proper height.

CHAPTER VIII.

Results and Cost of Irrigation.

There is an immense amount of data to be had regarding irrigation, and on that account only general results will be given in this chapter. With the usual methods, the suspended matter is completely removed or reduced to a few traces and the effluent is clear. In favorable cases the dissolved matter is reduced 90 per cent.; in the most unfavorable cases there may be a slight increase in the total amount. The total quantity of nitrogen may be nearly all removed or only a third or half withdrawn, according to circumstances. These differences are due to the different conditions of weather and crops during the year. With a proper plant and treatment, the irrigation process will furnish a purer effluent, both chemically and microscopically, than is found in many wells and brooks; and on that account it is possible that this process is the most successful method of sewage disposal. On the other hand, very unsatisfactory results are sometimes obtained. Analyses of the effluent from beds and fields in Berlin showed that it sometimes contained 30 per cent. of the amount of ammonia in the crude sewage, while 36 per cent. was found in the effluent from overflowed areas. In every case careful adaptation of the drains to the subsoil water is necessary. See note, page 287.

Under some circumstances it would be better to run the crude or partly purified sewage into a river, than to allow it to mingle with subsoil water and thus enter wells or springs. The irrigation process in Paris is stopped when high water in the river hinders the free discharge of the effluent, and the crude sewage is emptied directly into the Seine.

The effects of evaporation from fields treated in the first and second methods, outlined in the previous chapter, are comparatively without any drawbacks, but the evaporation from fields managed by the third and fourth plans is very bad, since the sewage remains stagnant over a coating of decomposing sludge.* In winter many receiving basins are necessary, but in summer the

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* See note, page 287.

sewage should not stand more than a few days at most. In the comparatively warm climate of England the process may be continuous, although in other places the addition of the sewage to the plants during the cold weather is regarded as injurious. At such times simple filtration may be employed, as is done on the sandy soil at Danzig. Complaints against the process have generally proved unfounded. The crops may be too rank under bad management, but usually make excellent fodder.

The results and cost of irrigation are to a great extent dependent upon the relation between the quantity of sewage and the extent of the fields. In order that the fertilizing value of the sewage may be utilized to its utmost extent, large areas are necessary, over which the water is repeatedly turned. Where the land must be of less extent, the agricultural aspect of the process is neglected, and the aim is to simply furnish a pure effluent. The latter case occurs more frequently. The best system is to have private parties control the sewage during irrigation, as is extensively done in Paris and, recently, in Berlin. Freiburg offers an interesting case of this sort. In this city a large meadow along an industrial canal had been common property for years, and was used for sewage farms. When the sewerage system with water closets was introduced, difficulties arose. In spite of the extensive area of the meadow, the sewage was not always purified, and polluted the brooks below the place more than heretofore. A regular and uniform treatment was no longer possible, and the sewage was used in a number of ways, so that, by an alternation of processes, the effluent was maintained in a good condition. Naturally private parties could not be allowed to choose their own methods of treatment in such a case, and the whole process was placed under municipal supervision.

The data upon which an irrigation field may be calculated are of two classes—relating either to the quantity of sewage or the amount of fertilizing ingredients contained in it. The quantity of sewage used on an acre annually depends upon the volume of the voids in the earth, but is not equal to it, since allowance must be made for aëration. About one-third the volume of sand is taken up by the voids, and of this amount one-half at the most should be filled with sewage at one time. With 6½ ft. depth of drainage an acre of sandy ground will therefore take up about 47,000 cu. ft. of

sewage at each flow; and if the land is treated 6 times a year, the total quantity that may be disposed of in this way annually is about 282,000 cu. ft. Looking at the matter from the second point of view, there are certain species of grass that will assimilate 291 lbs. of nitrogen per acre annually. The city sewage contains nearly 9 lbs. of nitrogen for each inhabitant annually; hence an acre must be allowed for each 33 persons, in order to obtain the best *agricultural* results. A larger extent of land is desirable for raising other crops, since sugar-beets require only 219 lbs. of nitrogen per acre annually, carrots 125, and other plants still less. On the other hand, greatly diluted sewage must be used at times, and a less amount of land will be then fertilized with the same quantity of sewage. Hence in England an "agricultural standard" of an acre for each 20 to 40 persons, according to the kind of ground, has been adopted.

From a purely sanitary point of view an acre might be allowed to more than this number of persons, since the purification can be effected by the soil as well as by plants. The surplus nitrogen will then be combined to form soluble nitrates, which will be washed away. As a "sanitary standard," therefore, the English have adopted an acre for each 80 to 120 persons, with surface irrigation and grass crops. The bed system allows a somewhat greater quantity of water to be used. A recent French regulation requires an acre for each 580,000 cu. ft. of sewage annually, and the irrigation fields for the annexed districts of Paris have been designed on this basis. A rough approximation is to have the fields as large as the city itself, and this rule is fairly good for a population of from 60 to 120 per acre. When the farmers have more generally adopted irrigation the municipal land for the purpose need not be so extensive.

Another method of estimating sewage irrigation is based upon the annual rainfall. An acre of land receives annually from 58,000 to 132,000 cu. ft. of storm water, although much greater quantities have been recorded. On account of the fertilizing ingredients of sewage, the latter should never equal the amount of pure water which can be removed from a field by drainage, and which may amount to 2,280,000 cu. ft. per acre annually. It is doubtful if the quantity of sewage that may be treated varies in proportion to its ingredients, since there is a limit to which even pure water can be applied to land.

TABLE IX.—APPROXIMATE DATA REGARDING SEWAGE FOR IRRIGATION FIELDS.

City.	Pop. per acre.	Sewage, cu. ft. per acre per year.	Sewage per capita per day, gals.		
			Dry days.	Rainy days.	Average.
Twelve English cities	61	73,000	..	...	18
	283	583,000	..	...	77
Berlin	133	175,000 / 219,000	18	40	26
Breslau	178	350,000	26	53	40
Danzig	203	482,000	40	61	48
Freiburg	49	1,167,000		..	...
Paris	267	526,000	26	66	40
Brussels, projected	40	131,000	40	79	66
Munich, "	162	....	40	106	...
Zurich, "	162	848,000	58	...	106

The relation between ordinary and storm sewage depends upon the number of relief outlets. The figures for dry-weather sewage do not agree with those given in the preceding tables, since the latter are based upon the assumed quantities, while this table gives the actual amounts at present treated. In Breslau, Danzig, and Zurich the subsoil and flushing water is included in the carrying water and the duty of the irrigation fields correspondingly raised.

The cost of preparing the surface of an irrigation field, including grading, ditching, etc., averages from $40 to $160 an acre, and the drainage comes to from $20 to $60. The total cost per acre in Berlin was $190, in Breslau only $83.

The proceeds of management is the difference between the entire outlay for labor and material and the receipts from the products sold. The work is generally managed by contractors, and the rent forms the proceeds.

In a number of English cities, the proceeds may be $200 an acre, and from that figure dwindle to nothing, or even show a loss. The average is about $50.

In Danzig a contractor received free use of the irrigating fields under the condition that he was to keep the sewerage system in order. The terms of the contract have, however, been recently altered. The proceeds per acre are probably from $18 to $24.

In Berlin the results vary greatly in the different years. The maximum net receipts per acre for a year are $13.10 from meadows, $19.30 from beds, and $20.60 from overflowed fields. The gross receipts average for each acre, $30 from meadows, $35 from beds, and $25 from overflowed fields, and the expenses average $9,

$12, and $12, respectively. Sometimes there is a loss. The average annual income from the city farms, of which 42 per cent. are now supplied with sewage, ranges from $8 to $14 an acre net, or from $13 to $40 gross. This money is partly devoted to paying the interest on the cost of the fields and their improvement, averaging $380 an acre, but the sums are not sufficient, and an appropriation of about $14 an acre is made annually. These figures are based on the reports of 1882–87 inclusive. See p. 287.

In Breslau the fields are leased at from $8 to $11 an acre annually, and thus pay about 1½ per cent. on their cost.

In Paris the rent of single fields ranges from $30 to $40 an acre, $25 more than their worth before the system was adopted, and more than the fields in the vicinity are worth.

In order to compare the treatment by irrigation with the other methods already discussed, it is best to reduce the units of comparison to the cost per 100 cu. ft. and the annual expense for each inhabitant. In this case, not only the proceeds of the process are to be considered, but also the expense of preparing the fields and their original cost, the interest on the capital invested, and possibly a sinking fund.

There is generally a loss, as noted above for Berlin. Special reports of 9 English cities shows that this ranges from 0 to 5 cts. per 100 cu ft. or from 0 to 50 cts. per capita annually. These figures show a greater range than those for chemical precipitation, partly explained by the cost of land and partly by the variable value of the crops. In the very satisfactory fields of Breslau the loss is only 6 cts. per capita annually. In Berlin the figures for 1885–86 are 1.2 cts. per 100 cu. ft. and 15½ cts. per capita, and these rates are slowly decreasing. The opinion prevails there that chemical precipitation would be more expensive and give less satisfactory results.

If no chemicals are employed and the mere mechanical precipitation will answer all requirements, the expense is much less than that of irrigation. In any case it is to be noticed that suitably designed and conducted irrigation fields come nearer to both sanitary and agricultural standards than any other method of sewage purification; and the method is capable of greater improvement, while the future of precipitating plants is uncertain as regards the removal and value of the sludge.

The total cost of a sewerage system must usually include some

system of sewage purification the cost of which is to be added to the figures already given in Part I. In Berlin the figures per capita per year for 1885–86 are as follows :

Interest and sinking fund, 4 per cent. of $12	48 cts.
Running expenses, including pumping	17 "
Sewage purification	15 "
	80 cts.

To meet this expenditure each landholder pays in taxes for the purpose, on an average, 36 cts., and the saving in street cleaning due to the sewerage system is reckoned at 15 cts.

PART III.—GENERAL MUNICIPAL AND DOMESTIC SANITATION.

CHAPTER I.

The Sanitary Problem.

The problems of municipal sanitation relate to the disposal of: *a*, refuse or dry matter from streets, dwellings, and industrial establishments; *b*, excrement; *c*, waste water from houses, shops, streets, and public springs; *d*, storm water; *e*, subsoil water.

Formerly, the reason for removing and disposing, in various ways, of the above matter, rested simply on a desire to preserve an agreeable and decent condition of affairs within the city limits, but recently the subject has been regarded with increasing interest from a hygienic point of view, and various more or less theoretical assumptions have been made concerning the relations between municipal cleanliness and disease.

When the chemical processes of fermentation had been examined and explained, it was but a single step to the general theory of the disassociation of organic bodies and the spread of contagious or infectious diseases. In the latter, as in the former, there was a formation of ferment, in small masses at first which grew and spread to other bodies. Partly by direct experiment and partly by analogy, this ferment, it is thought, consists of minute organisms, or bacteria, generated by decomposition.

For the present purpose those bacteria which act upon man are of chief interest. They are extremely small, multiply rapidly, and live within the body without the presence of free oxygen. They are found everywhere in the atmosphere, and often in water if it contains their proper food. Fortunately all species are not disease germs, although many investigators hold that there are but a very limited number of kinds, any of which may be dangerous under certain conditions. Nevertheless, a distinc-

tion can be drawn between the bacteria of decay, of miasma, and of contagious disease.

They are all important from the point of view of the sanitary engineer. Their presence and increase necessitate dampness. They cannot, however, leave the place where they have been formed without outside aid, and are scattered by a flow of water, winds, on particles of vapor, or after drying, as dust. They are not killed by drying but simply benumbed or crippled, and their vitality may remain unchanged for days or weeks under such circumstances. In pure water they also remain torpid and do not increase, although still living. The more organic matter on a damp surface, the more tenaciously do they adhere; the more inorganic present, the more easily are they scattered.

Contagious matter may be absorbed by breathing, eating, drinking, and through skin wounds. For every class of bacillus there is an especially adapted method of contagion; typhoid and cholera germs enter the stomach, consumption and malaria bacilli reach the lungs, and others according to their nature. Unfortunately, there are a number of ways by which each class may reach the part they especially affect.

1. *Putrefaction.*—All organic matter in refuse, excrement and domestic wastes, like all organic matter from a living being, is subject to a series of chemical and physical changes which finally leave it in the form of stable inorganic compounds, the whole process being conveniently named "mineralization." The changes are divisible into those of oxidation or of putrefaction.

Where there is no oxygen, putrefaction takes place. The organic matter, in the presence of water, finally changes to gaseous products, ammonia, hydrogen sulphide, carbonic dioxide, and others, generally with a very bad odor and sometimes poisonous. Wherever there is putrefaction, especially when the supply of air is much limited, there is a bad odor. The greater the amount of air, and therefore oxygen, the more quickly will oxidation take place, generally without odor, and resulting in the formation of carbon dioxide, nitric acid, sulphuric acid, and similar compounds. Many organic substances of a complex character cannot be directly oxidized and must first decay; in this way fatty acids are changed to carbonic acid and ammonia, and the latter to various nitrates. Decay occurs in ditches, heavy or damp earth, stagnant water; oxidation takes place with free access of air in

porous or dry earth or in flowing water. Both processes may occur simultaneously, decay within and oxidation without the body.

Corresponding to the difference between oxidation and putrefaction is a difference between the bacteria attending the two changes. One kind requires the presence of oxygen and aids the decay of fruit and dry rotting of wood, thereby causing, or attending, the diseases of plants. They can only attack those portions of man which have free access to the air, and are therefore comparatively harmless. With their slow development and inability to exist without free oxygen, they are effectually prevented from penetrating into any tissue. The bacteria of putrefaction have directly opposite characteristics, and have always been regarded as injurious. The pathological characteristics of putrefying matter and bacteria of putrefaction have not been clearly separated as yet. In general, it may be said that experiments show that putrefying matter is more injurious than the bacteria. Two extensive investigations with bacteria and healthy tissue have proved that "putrid" water from which the germs have been removed is still poisonous, while the bacteria themselves are harmless. The experiments are extremely difficult owing to the presence of bacteria in the air, and the results are therefore liable to be in error. It is accordingly open to question whether man is more liable to disease from putrefying matter or from the attendant bacteria. The practical fact is evident that a removal of the matter will at the same time reduce the danger from the germs.

In all cases the habits of the individual have a great influence on his susceptibility to disease. Many persons accustom themselves to the presence of excrement, the use of bad food or contaminated water; others are immediately affected under similar conditions. The quantity of putrefying matter has been experimentally proved to be of considerable influence in this connection. On injecting such substances into the stomach or blood of animals, it was found that, by dissolving a definite amount of a poison of putrefaction in water, the effects were weaker than when the undiluted poison was used.

2. *Dampness in the Ground.*—Where storm water is absorbed by the earth or enters into cellars through defective draining a considerable danger is caused. Capillary action and subsequent evaporation will keep the walls of such buildings constantly

damp and cool, and cause catarrhal and rheumatic complaints. Damp walls and floors are also impervious to air, and hinder the ventilation of a house. The presence of bacilli in the complaints mentioned has yet to be proved, but they certainly occur in the miasmal diseases. The bacilli of miasma are generated on or slightly below the surface of damp earth in the presence of vegetable mold. Where subsoil water occurs, they exist on the surface in a slight depth of earth where the best nourishment is to be found, but do not penetrate very deeply. Investigations in Berlin have failed to find them at a depth of $3\frac{1}{4}$ ft. The subsoil water is therefore so far injurious as it tends to cause dampness on the surface. The greater the amount of organic matter in such earth, the more nearly do the bacilli resemble the bacteria of decay.

The bacilli of contagious disease, those which are given off from the sick in various ways, are liable to affect the person upon whom they lodge. They have never been seen to originate, and have only been known to multiply, within the tissues. They carry disease from individual to individual, both by actual contact of a sick to a healthy person, and by transmission on portions of diseased matter. In this way contagious disorders are spread, not only by actual touch with a diseased individual or any secretion from his person, but also by his clothes, and even the air in his neighborhood and water in which bacilli have been absorbed. Naturally the methods of transmission from one person to another are widely diverse, and it is to be noted that the bacilli of contagion are the most injurious of any in proportion to their numbers, are more tenacious of life, and develop more rapidly than the others. They are only surely destroyed at a high temperature or by strong disinfection.

CHAPTER II.

General Principles.

The problems of city sanitation are solved in the following manner. The matter subject to decay is to be removed from the vicinity of dwellings as speedily as possible, especially when it contains substances which simply require to be moistened in order to decompose, or secretions from diseased persons. Such portions of this matter as remain near or in buildings will soon give off offensive gases and bacteria, and on that account sanitary building and disinfection are necessary. If the organic substances sink into the earth, the compounds which result from their decomposition will remain to some extent in the soil, and to some extent enter springs and wells, dissolved or suspended in water used for domestic or other purposes. Subsoil water must be taken into consideration as forming a means of transport of sewage and similar matter from one place to another, and the drainage should therefore extend to hard-pan.

The cleaning and sewering of a place is naturally a public duty, since it must be systematically done, and individuals must be forced to remedy defective or careless arrangements. The management is generally public, but special duties, such as the removal of different classes of refuse, are sometimes let to contractors, who do the work under municipal supervision. Systematic work is desirable on both sanitary and financial grounds, especially when there is a possibility of an increase in the extent of the city by annexed districts.

Two equally bad customs are to be mentioned in this connection. One is the practice of heaping streets and building lots with rubbish from new buildings, and earth which contains organic matter. In filling in around foundations, cinders and similar substances are to be avoided, since, in connection with water, they will cause deposits of sulphur and nitrogen compounds on the walls, injurious to the mortar.

The second bad custom is the continued use of ditches and sewers with porous walls. The ordinary privy retains only the

solid excrement and allows all the liquids to mingle with the subsoil water. Apart from the inconvenience of decay, stoppage, and removal of solid matter, the infection of the soil and water is sufficient cause for a city to forbid the use of such devices except for the domestic wastes of isolated buildings.

It has been shown in many places by carefully compiled statistics that thorough and careful regulation of city cleaning and sewerage improves their sanitary character. The sensitiveness to epidemics, especially cholera and typhus, has diminished, which fact is especially noticeable on comparing different parts of the same city. Some chronic complaints, especially miasma, have been entirely dispersed after their cause has been removed. The gradual decrease in the mortality rate also points to the same conclusion. To be sure, other regulations, both architectural and moral, and the introduction of large water-works have contributed to this result. It cannot be denied, however, that in some cases the mortality has increased in spite of improved sewerage and has decreased in others without the introduction of better sanitary regulations. The causes of this are manifold, and statistics show only the final results, not the influence of each relation which can influence the public health.

In spite of the great advantages of health and convenience for traffic and industry, an ideal system of municipal sanitation is not always possible. Very often the cost of plant and maintenance must be carefully considered in comparison with the prospective results. Since the latter cannot be determined beforehand with any accuracy, and are not reducible to a monetary basis in any case, the merits of different plans depend to some extent on individual preferences and prejudices. In general, a wealthy and hitherto unhealthful city is warranted in expending a greater sum of money than a city with smaller financial resources and better sanitary conditions. There are many moderately successful and comparatively inexpensive methods of cleaning and sewering a place that are not to be overlooked, although not the most successful. Public health is a possession or condition which must be paid for, and the greater the expenditure the better are the results usually.

CHAPTER III.

THE USE OF GUTTERS.

Gutters were the first means of removing storm water from a city. They embrace street gutters, running parallel to the axis of the street; transverse gutters from the rain pipes on the front or interior of houses, or from between separate buildings; and occasional secondary branches to courts or rear areas. In addition to their hygienic disadvantages, which are lightly regarded as long as the cleaning is systematic, the gutters, if of some length and width, are liable to hinder traffic, by flooding streets and cellars, or by causing icy places and bad roadways, especially at

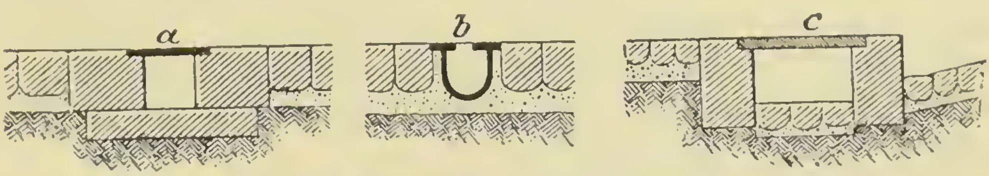


FIG. 145.—SECTIONS OF GUTTERS.

street intersections and private entrances. All land must be higher than the gutters, in order to be drained. These disadvantages may be partly remedied by the use of covered gutters, similar to those illustrated in Fig. 145. The first form, *a*, has a cover of wood, iron, or stone; the second, *b*, is a simple slot conduit, easily cleaned and also easily choked; the third, *c*, is the most expensive.

The disadvantages of surface drainage can only be overcome by underground sewers, generally at a greater expense. Therefore the system of gutters is still allowable in some cases, such as the following: In small places or in manufacturing establishments where the traffic is light; where the gutters are short, as in cities lying along a river or crossed by numerous water-courses, like the Dutch towns; where there is a steep grade, causing the water to run off quickly; where a cheap temporary drainage system is required. In old sewerage systems, the street gutters were the usual channels for the removal of all storm water, and are still used for this purpose in Freiburg, Salzburg, and Basel, in order to

spare the householders the expense of underground rain-pipe connections.

The gutters are also used in many cities as channels for the removal of waste water. In such cases, in addition to the obstruction of traffic already mentioned, sanitary and æsthetic objections arise; for while all the polluted water is swept away during storms and the street refuse is washed off, new drawbacks present themselves which are even more serious. On account of lack of water, and owing to frost, deposits may be formed which will taint the air. Only by repeated flushing with water from streams or water mains, as in Paris and Hannover, can the waste water be prevented from stagnating and causing deposits; these remedies are, however, only useful in summer, and are of little aid in the rear of houses. Hence regulations in some places require the waste water to be carried from the houses to the gutters, and even to special emptying places along the line, during the winter. This practice is both laborious and unclean. Where regular flushing is impossible a privy on each lot would be better, from a sanitary point of view. In Dresden, privies are required where there is no sewer connection, and the gutters are not allowed to be used for such matter.

Although gutters are not adapted for removing waste water, nevertheless their use is allowable if disinfected, even when urine is present. The water may be disinfected in receiving basins where it is constantly agitated, in a filter vat where solids are mechanically removed, or in a disinfecting ditch for excrement. There should be a thorough treatment, since any excess of the disinfectant will act beneficially on the storm water. In this way a surface sewerage system is possible without any injurious vapors or contamination of the soil. The plan is recommended by Petri, but is practicable in exceptional cases only, for in addition to the obstructions to traffic of such a system, it would be impossible to drain low courts or cellars, or to influence the height of subsoil water, and the prevailing odor of carbolic acid might be as undesirable as that of decaying matter.

CHAPTER IV.

Quantity and Character of Refuse.

1. On the streets and squares of a city there is always collecting a quantity of dust, leaves, manure, paper, and similar matter, which together form the so-called "sweepings." The quantity depends entirely on the material and construction of the pavement and the extent of the traffic. From English investigations it is usual to assume that the sweepings from stone pavements are from a half to a sixth the quantity from macadam ; from wooden pavements, a sixth to a twelfth ; from asphalt, about one-twelfth. In Berlin the average quantity of sweepings has been continually decreasing since 1880, in spite of an increased area and traffic, which clearly demonstrates the value of good pavements.

The quantity of refuse varies greatly with the weather ; on asphalt pavement the volume may be half as much again in wet as in dry days, and on stone and macadam from 2 to 5 times as much. This is due to the fact that mud will be carried continually from the poorly paved streets to the better ones by the wheels of the passing vehicles.

The most important constituent of this rubbish is the organic matter. In Bremen 0.2 per cent. of the sweepings are nitrogen, and 0.4 per cent. in Breslau and Brussels. London sweepings from stone pavements during dry weather contain, according to Letheby, 58 per cent. of organic matter, and 20 per cent. during rainy days. Under similar conditions the average with stone pavements was 23 per cent., wooden pavements 60 per cent., and macadam 4 per cent., the comparatively small amount in the last case being due to the large amount of dirt from that class of surface.

In addition to the actual street sweepings, account must be taken of the deposits in sewer inlets and the sewers themselves. In London 80 per cent. of the refuse removed comes from the streets, 17 from the inlets, and 3 from the sewers : and the total mass is estimated to consist of 40 per cent. of abraded pavement, 40 per cent. water, and 20 per cent. organic matter.

2. The domestic refuse consists of house sweepings, kitchen

wastes, and ashes, the quantity of the latter being about three times greater with coal than with wood. Other matter—such as builders' rubbish, garden refuse, the waste from the kitchens of large hotels, and ice—is removed in some places by private and in others by municipal laborers. Where the private owners are obliged to do this, many disagreeable consequences may arise, and public contractors are deterred from bidding on such work, owing to the uncertainty as to the quantities they may have to handle. A fairly good compromise is in force in Stuttgart, where the contractors remove all but a small part of the general refuse, and the remaining matter at the request of the householders at the rate of 18 cts. per cu. yd.

The house refuse is collected either in movable barrels and boxes or in pits and ditches. The inorganic and organic matter should be kept separate as much as possible, since they are used for different purposes, and when combined are of little or no value, as well as injurious from a hygienic point of view.

Municipal regulations usually prescribe the form and material of the movable receptacles. In any case the barrels or boxes standing in front of a door make a far from pleasing impression on the beholder, especially when not regularly emptied. The Bremen system is better on this account. There the pails and barrels are placed in underground recesses, from which they are removed and emptied by the regular street-cleaning laborers. The receptacles should be large and easily reached by all the dwellers in the house, as well as by the laborers who empty them. In Leipzig the size is sometimes sufficient to hold 6.4 cu. ft. They are made of wood, with a metal lining, or entirely of metal, preferably the latter, and should have a tightly fitting cover.

Pits and ditches afford more room for collecting and retaining the refuse, but the delay in removing the matter from them may result in disagreeable or serious consequences, and more than two weeks should never elapse between successive removals. Moreover, separate pits for ashes and rubbish are to be recommended. The ash pit may be quite large, but the other need not contain more than the refuse of two weeks. Their size can be approximately estimated by allowing 0.5 cu. ft. of ashes and 0.25 cu. ft. of rubbish per week for each person in the house. Both pits should be easily reached from all parts of the house and from the street,

and should be protected from rain. They are best made of stone, brick, or concrete, as giving greatest security from fire and injurious vapors.

These pits are sometimes connected with the different compartments by chutes, in which case care must be taken to secure good ventilation, and an easy access for removing the collected matter. A more simple plan is to have the chutes discharge into movable receptacles of some sort.

3. Manufacturing and industrial establishments collect very large quantities of waste matter, which is usually removed by private contract, although the English system of removal by the municipal laborers at a special price has some advantages. Where matter liable to decay or putrefaction, or substances of an acid nature or giving off unpleasant odors, occur, special receptacles should always be provided. Manure pits should be protected from rain and be drained by underground connections.

The following table gives a series of interesting statistics regarding the quantity of refuse from different cities, and embraces the classes described under 1 and 2 above, and to a less degree under 3 :

TABLE X.—QUANTITY OF REFUSE. CUBIC FEET PER YEAR.

City.	From streets.		From houses.	Total.
	From each lineal yard.	Per capita.	Per capita.	Per capita.
Amsterdam	20.3	10.6	....	....
Baltimore	18.4	....	....	....
Berlin	17.5	6.0	8.8	14.8
Boston	11.6	....	....	....
Bremen	....	6.4	7.8	14.2
Cologne	....	....	....	17.0
Copenhagen	....	2.1	9.2	11.3
Frankfurt	1.6	1.8	7.8	9.6
Hague, The	9.7	11.7	....	....
Hannover	4.5	3.5	....	....
Karlsruhe	....	....		19.1
London	6.8	5.3	26.5	31.8
Liege	10.6	11.7	....	....
Manchester	....	....	28.3	....
New York	21.7	....	....	....
Paris	32.3	14.1	12.4	26.5
Philadelphia	10.6	14.8	25.5	40.3
Rome	21.7	15.2	3.2	18.4
Rotterdam	....	....	....	19.8
Stuttgart	10.0	5.6	3.5	9.1
Vienna	38.8	16.6	12.0	28.6
Average of the above cities	15.8	8.8	11.7	20.5
Assumed value, BUERKLI	....	....	....	14.1
Assumed value, KNAUFF	....	5.6	11.0	16.6

Special measurements in Berlin show that a cubic yard of street sweepings weighs from 1,680 to 2,190 lbs., according to the amount of water present, the average weight being 2,100 lbs. House refuse averages about 840 lbs. Measurements in Bremen and Stuttgart show that both classes together average 1,180 lbs; in Berlin the weight is assumed at 1,360 lbs.

CHAPTER V.

Implements for Street Cleaning.

The hand implements are either scrapers or brooms. Wooden scrapers preserve the surface better, especially with macadam, while those with iron blades have more effect on the dirt, especially when compacted. If the streets are dampened by showers or sprinkling, rubber scrapers can be used. They are

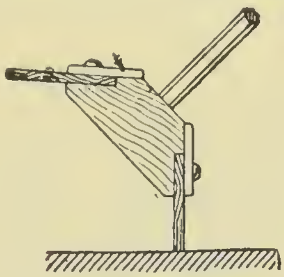


Fig. 146.

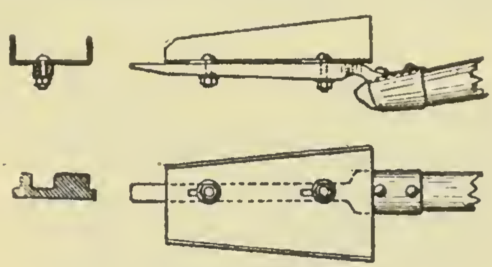


Fig. 147.

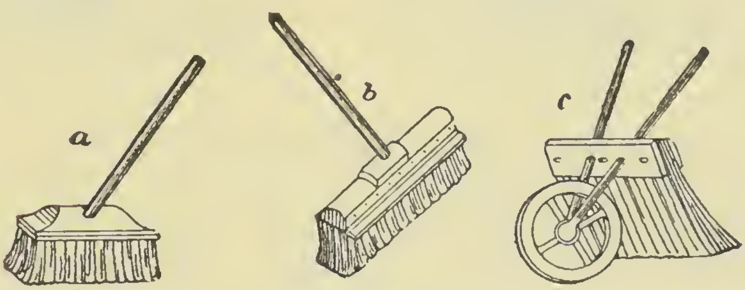


Fig. 148.

made by fastening a rubber plate, about three feet long and four inches wide, between two pieces of wood, to which a handle is fixed. Occasionally two plates of rubber are used, as shown in Fig. 146. For cleaning tracks on street railways iron trowels fitting the rail are used. As they are pushed along the dirt is thrown to one side or collected in small pans attached to the top of the scraper; see Fig. 147.

Birch brooms are too weak for street sweeping. Steel-wire brooms are more efficient and last longer, but are apt to injure macadam. The broom head is usually about 16 by 4 ins., and is sometimes provided with a rubber plate for scraping; see Fig. 148, *a* and *b*.

Scraping is only allowable on smooth surfaces; elsewhere

sweeping is more satisfactory, except with tenacious accumulations. Hence the cleaning is usually done in both ways, the two methods being employed in proportions determined by the weather and condition of the street. Where the work is done frequently, only brooms are to be used on macadam, and scrapers should not be employed on wood or asphalt until the surface has first been swept and, if possible, sprinkled. It is usual to begin cleaning at the axis of the street and remove the refuse toward each side, where it is collected into heaps easily removed.

The rapidity with which the work may be done by hand labor varies greatly with the character of the street and the skill of the laborer. Excluding exceptional cases, a large number of investigations show that one man can clean hourly from 350 to 840 sq. yds.

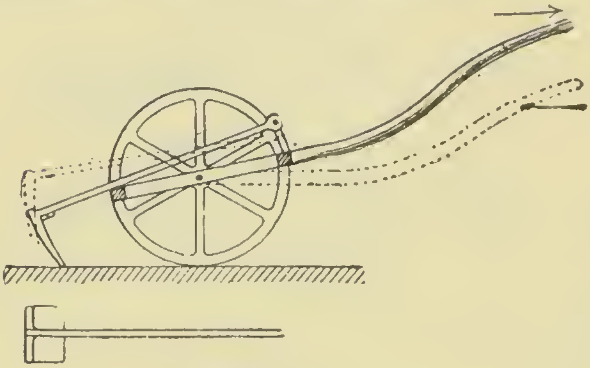


FIG. 149.

In Paris, the device shown in Fig. 148, *c*, was adopted for the purpose of increasing the area swept by each man, by lightening the manual labor. The broom, about $3\frac{1}{4}$ ft. long, is carried by a single wheel, which bears the greater part of the weight. In the two-wheeled scraper, shown in Fig. 149, a number of iron teeth are set in a frame $3\frac{1}{4}$ ft. long.

The removal of manure is best done by hand, especially on asphalt pavements, since it must be quickly effected if slipperiness and unsightly streets are to be avoided. It is usually accomplished by boys with brushes and bags or pans, which are emptied in proper receptacles beside the roadway. These receptacles may be small pits below the sidewalk, or large hollow posts 4 ft. or more high, tightly closed in any case.

Cleaning machines, pulled by horses, are now widely used; Fig. 150 represents a rotary sweeper and Fig. 151 a horse scraper, with iron teeth 3 to 5 ins. wide, attached to the frame in such a manner that they will give on encountering any fixed obstacle. The rotary sweeper has a long cylindrical brush driven by a chain or gearing from the axle. Both the brush and scraper can be raised from the ground when desired, and are inclined at an angle of 45° to the axis of the street, so that the rubbish is col-

lected in the gutters. Larger brushes, drawn by two horses, are sometimes employed, and in all sizes it is possible to change the inclination of the brush itself from one side to the other. They will sweep a strip of road from 5 to 6½ ft. wide at each trip, and a number are often employed at the same time, each following and a little to one side of the preceding one.

Sweeping should always be preferred to scraping except where the dirt adheres closely to the pavement or is present in large quantities. There is always a danger of loosening the pavement when it is scraped; hence, the number of brushes in use far exceeds the number of scrapers. Numerous investigations show that these cleaning machines can cover from 4,800 to 10,800 sq. yds. an hour, and will do the work of from 10 to 20 men. The

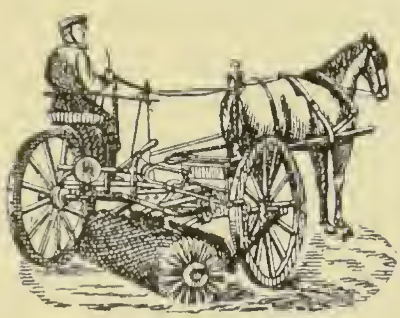


FIG. 150.

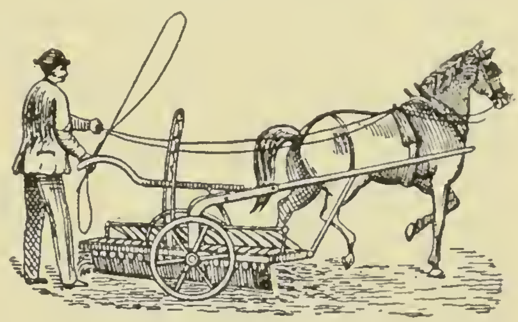


FIG. 151.

economy resulting from their use may be as great as 80 per cent., and falls from that figure to an inconsiderable amount. Hand labor holds its own wherever small surfaces are to be cleaned or the work must be repeated at short intervals. In the reorganization of the street cleaning department of Hamburg, a little more than a half of the street surface was assigned to machine sweepers.

Their great advantage lies in the rapidity with which the work is done, causing little inconvenience to the traffic and enabling the refuse to be collected before it dries and becomes hardened. Uneven surfaces cannot be cleaned in this way, and in any case bad pavements are more difficult and expensive to clean than those in good condition.

A number of machines for sweeping and removing the dirt have been invented, but have not proved satisfactory. Usually they will only take up a portion of the dirt and leave the street only partly clean. A recent device for street cleaning consists of a combination sprinkler and brush, and has the advantage of collecting the rubbish without raising any dust.

CHAPTER VI.

Removal of the Rubbish.

The cleaning of streets was, until a comparatively recent date, always left to the householders, and even now they are required to keep part or all the paved streets in condition in many German cities. Where the traffic is moderate in volume and the area of the streets not very large, the labor of keeping the pavements clean is not at all arduous. In Nuremberg, Munich, and Strassburg the householders are not required to clean all the street from the house line to the center, but only a certain part, 8, 5, or 4 meters wide, leaving a strip down the center of the roadway to be tended by the city, which is also always bound to clean the parks. In some cities the city looks after the roadway and the householders the sidewalk, the gutters being sometimes classed with the former and sometimes with the latter. This system is nearly universal for highways, where the length of road before each house would make the duty of cleaning the surface very heavy. In Altona, Berlin, Bremen, Hamburg, Mainz, Cologne, and Karlsruhe all the cleaning is done by the municipal authorities.

In view of the modern tendency to construct broad streets and the greatly increased traffic of the present time over that of a few decades ago, it is doubtless desirable to place the duty of street cleaning in the hands of municipal authorities, for the expense would finally become too great to be borne by private parties, and the work can be done more economically and satisfactorily under one single direction.

Where private cleaning is in vogue, the general rule is to have certain hours fixed by the city on two or three different days in the week, when the sweeping is to be done. Daily cleaning is required in but few places, Breslau, Duesseldorf, Munich, Strassburg, and Stuttgart. Where the work is done by the city, the streets can be divided into groups requiring to be swept every week, 5, 4, 3, or 2 days or daily. In the much-frequented streets in Hamburg and Frankfurt, and on nearly all in Berlin and Paris, the work is done between midnight and 6 o'clock

in the morning, thereby reducing the inconvenience to vehicles to a minimum.

The rubbish should be removed as soon as possible after collection. When the sweeping is done during the night, the immediate removal necessitates a larger number of carts than when the heaps may be allowed to stand for some time. The slowest and most incomplete work is done when the householders are required to dispose of the matter, which is frequently done by throwing it all into the catch-basins of the sewerage system.

The house refuse is generally removed in small towns by the people themselves or by their contractors. Such a system does not always result in so good and frequent service as is desirable from a sanitary point of view; and on that account a number of cities have made obligatory the use of the public department for removing this matter. Where removable receptacles are used, they are emptied sometimes daily and sometimes only two or three times a week. The hour at which the work is to be done is fixed as nearly as possible, but at certain seasons there may be large quantities to be handled, and the work will be correspondingly delayed. Occasionally, when local conditions are favorable, both street sweepings and house refuse are removed at the same time; but generally the two classes are collected separately, the same laborers being employed on both classes of work wherever it is practicable.

At present the work of removing the refuse, when under municipal control, is sometimes done by the city laborers, and sometimes by contractors. Aachen, Bremen, Hamburg, and Stuttgart give over all the work of cleaning the streets to contractors. The city usually does the work only under special conditions, and then only on a limited extent of street surface. Breslau, Frankfurt, and Cologne are probably the largest German cities where all the work is done by the city laborers. In such cases the horses of the fire department are used on the carts of the cleaning department, and occasionally the fire and cleaning departments are consolidated. Sometimes the streets are cleaned by the city, and the refuse removed by contractors, either for the whole work or for supplying the horses only. This system is generally adopted by large cities, and is probably the most suitable. A proper cleaning of the streets requires so many tools and fairly skilled laborers that a contractor would not care to undertake such work except on a

long contract; the removal of the matter is, however, a simple matter, and if done by contract relieves the city of the management of large stables. The carts are best furnished by the city, since it will then be certain that they are properly constructed.

Except in Berlin, Karlsruhe, and Hamburg the carts are not covered and are often not tight; consequently the light dust from the dry refuse is blown about by the wind and the mud oozes over the sides or through cracks. The best forms, holding 3 or 4 cu. yds., are shown in Fig. 152. The first, *a*, is made of

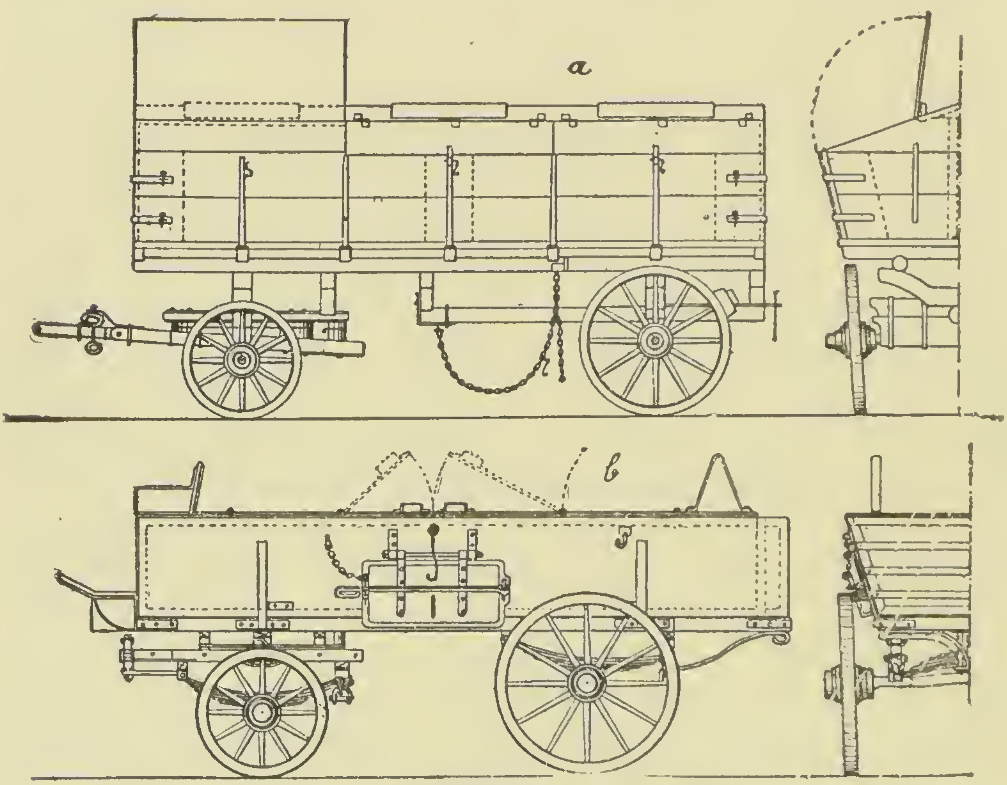


FIG. 152.—GARBAGE WAGONS.

wood, with iron lids; the second, *b*, is entirely of iron. They are emptied through the side, either by a door, as in *b*, or by dropping the whole side, as in *a*. Large two-wheeled dump-carts are used in cities along the Rhine. The sludge from inlets and sewers is usually removed in closed carts, but the work is performed slowly, as a rule, and gives rise to great inconvenience. Many special appliances have been proposed, the best of which are those manufactured under the GEIGER patents, and shown in Fig. 153. The cart carries a crane which can be moved across it and turned in all directions. The different motions of the parts are controlled by cranks and gearing, and the sludge buckets, see Fig.

70, are quickly emptied and replaced. The carts are emptied by tilting the body on the rear axle, by means of a crank and gear engaging a quadrant rack, and allowing the contents to slide out of a door in the back. The whole operation much resembles the way coal is handled in many American cities.

The dumping places should be so chosen that there will be no nuisance from odors or dust, and the land will not be rendered useless in case an extension of the city should require more room for houses and other buildings. The refuse should be sorted when it is likely to contain enough junk to make the work profit-

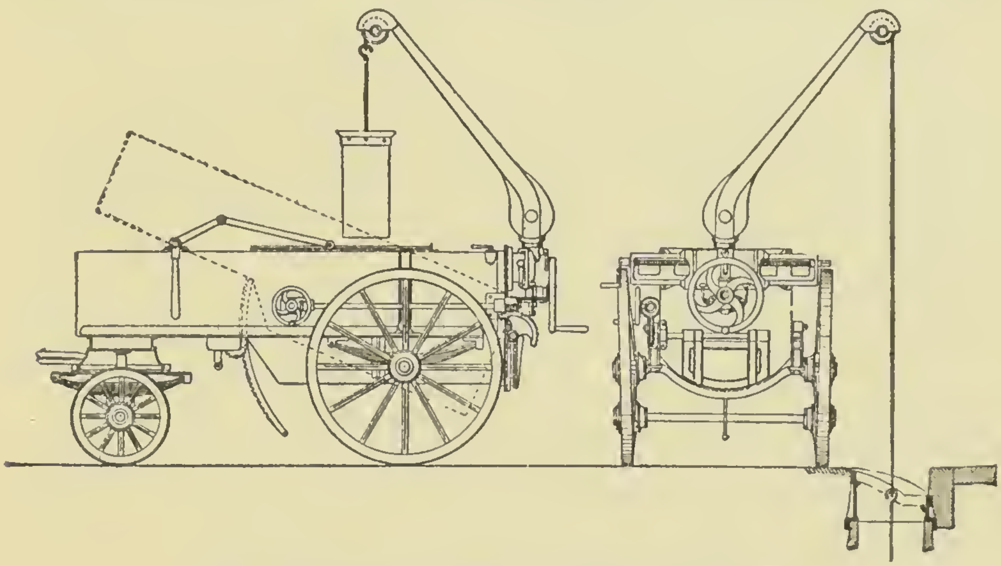


FIG. 153.—GARBAGE WAGON, GEIGER SYSTEM.

able. The work is usually done by hand, sometimes aided by sieves, as in Glasgow, where the refuse is sorted into fine ashes, cinders and general rubbish in this way. Pieces of metal, bones and rags usually have a market value ; ashes and slag are worked up into mortar or used in brickyards ; cinders are burned again ; organic matter is worked up as a fertilizer ; only vegetable matter seems to be valueless. Street manure is worth from $2 to $2.50 per 100 cu. yds. in Berlin and about 25 cts. a ton in London. In Nottingham the fine tailings from sieves through which house refuse passes are mixed with the refuse of markets to form fertilizers. In other places proper proportions of house and street refuse are formed into compost heaps, and a good income is derived in this way, especially in Breslau, Frankfurt, and Strassburg. Even the waste from new buildings is occasionally of use on account of its lime.

It is generally desirable, however, to dispose of the rubbish in the quickest possible manner. This may be done in garbage cremators, somewhat widely employed in England and America. Sometimes the refuse is picked over for junk before burning, but the labor is seldom repaid, and it is usually expedient to remove only those things which retard the cremation or destroy the value of the product. Where there is a considerable amount of cinders and organic matter in the garbage, it is probable that the burning will pay for itself by using the heat of combustion for raising steam. The furnace shown is Fig. 154, invented by FRYER, is continuous in operation. The garbage is fed into large chutes and the waste gases led away through the chamber x to the chimney or under a boiler, where steam may be generated for a pulverizing mill, through which the ashes from the process are run preparatory to being mixed with lime to form cement. Furnaces of this sort have been made large enough to dispose of 100 tons of garbage a day. Each grate will take from 2 to 7 tons per day of 24 hours and give from 0.5 to 1.75 tons of ashes. It is sometimes desirable to char the vegetable and animal substances in a special furnace with four grates from which the heated gases rise between the double walls of the chambers. Each chamber will char $2\frac{1}{2}$ tons daily in a furnace of the form shown in Fig. 155, which is drawn to a scale of 1 : 240. The process is rarely used.

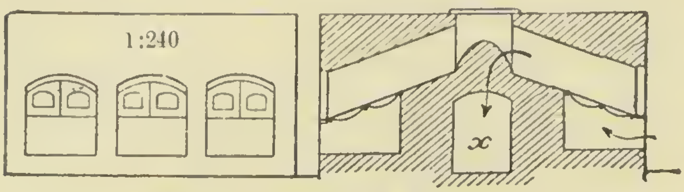


FIG. 154.—GARBAGE FURNACE.

In New York, Liverpool, Dublin, and similarly situated places the garbage is loaded on suitable lighters and then dumped outside the harbor.

In general, the cheapest and best way to dispose of the garbage of a large city is by the following treatment or separation :

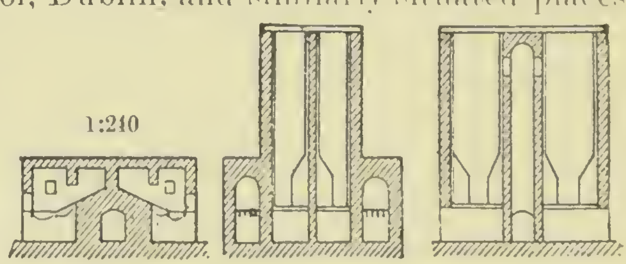


FIG. 155.—CHARRING FURNACE.

a. The marketable portions — iron, rags, etc. — are to be picked out in closed and ventilated buildings. This work is called "trimming" in some cities.

b. Mineral matter, ashes, cinders, etc., are to be separated, if valuable, for filling in low land.

c. Garbage with any fertilizing value may be also separated.

d. Other matter should be burned.

The amount of data regarding the cost of street cleaning is extensive, but difficult to use in comparative statements, owing to the different regulations in force in the cities. The following figures were mostly taken from reports of 1884–86, and give the annual cost of complete street cleaning and removal of garbage, exclusive of the cost of sprinkling and removing house refuse :

Per capita : Hamburg and Mainz, 12 cts.; Berlin, 30 cts.; Frankfurt and Hannover (only roadways), 22 cts.

Per 100 sq. yds. of street surface: Hamburg, $1.04. Berlin, with stone pavement and weekly cleaning $1.46, with daily cleaning $8.35, averaging three cleanings per week ; asphalt is $2.71 higher than stone; the average over all streets is $4.18. Paris, paved streets only, $6.25 ; all work including sprinkling, $5.45. Vienna, $6.90. London, $6.25. New York, $5.00. Philadelphia, $1.88. Average of several English cities : Granite, $3.33; asphalt, $3.97; macadam, $10.45.

Per yard of street length : Berlin, 87 cts.; Paris (including sprinkling), 92 cts.; Vienna (including removal of domestic garbage), $1.05 ; London and Manchester, 71 cts.; New York, 69 cts.; several other cities in America, 12 to 30 cts.

The cost of removing domestic garbage is difficult to determine. In Hamburg the work is done by contract at a trifle over 11 cts. per capita annually. In American cities it is 1½ to 2½ times the cost of street cleaning, which is very low in those cities.

The cremation process costs, exclusive of interest on the plant, from 5 to 12½ cts. per ton of garbage ; including interest, from 20 to 37½ cts. Where the ashes are worked up into cement the cost will be materially less.

CHAPTER VII

Miscellaneous Regulations Concerning Streets.

1. *Sprinkling.*—It is customary to sprinkle streets with water on warm days, both to lay the dust and to cool the air. Sometimes this is done by the householders just before sweeping the streets, when that duty falls upon them, as in Augsburg, Darmstadt, Heidelberg, Stettin, and many smaller places. In other

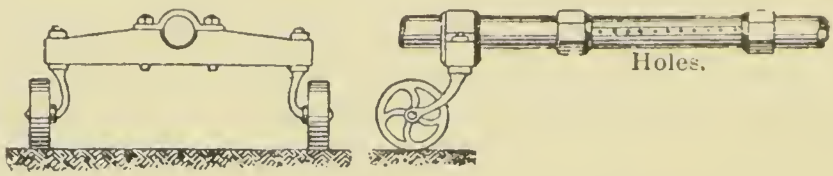


Fig. 156.

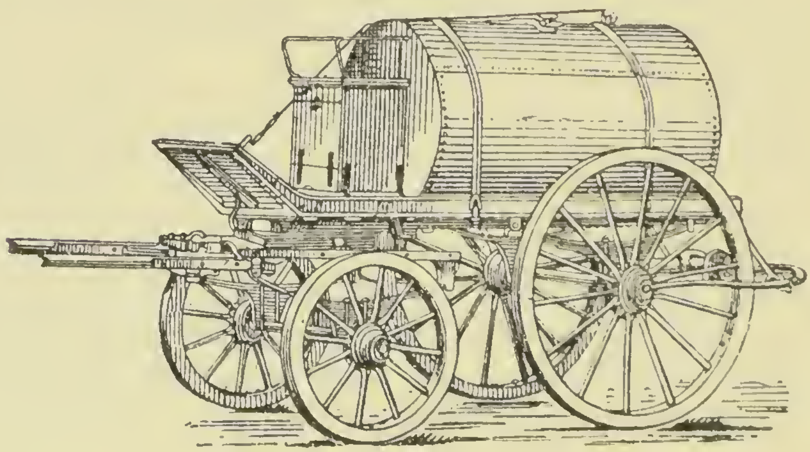


Fig. 157.—German Sprinkling Cart.

cities, such as Karlsruhe and Stuttgart, only the sidewalks are sprinkled by private parties. In the majority of large cities all this work is done under municipal supervision. Three methods may be followed. The city may do the whole work by its own laborers; the entire work may be let to contractors; the city may furnish the implements, and the work may be done under contract. The latter plan is generally the most satisfactory.

Where there are water mains the sprinkling may be done from hydrants, as in Hamburg, Zurich, Brussels, and Paris. Since an ordinary hose is soon worn out by being rubbed over the pavements, metal tubes have been employed in this work. They are

usually in lengths of $6\frac{1}{2}$ ft., mounted on little two-wheel trucks, Fig. 156, and connected by joints of flexible pipe, so as to roll easily in any direction. WERTHEIM has introduced a reel on which an ordinary hose is coiled in such a manner that the portion not required to reach from the hydrant to the place where the sprinkling is being done remains on the reel. The objections to this method are the obstacles to traffic due to the lines of hose or pipe, the unequal distribution of the water, and the injury that a strong stream of water may cause to macadam roadways. On the other hand, asphalt is best cleaned in this way, and grass plots are easily watered by the same means.

In Fig. 157 is represented one of ECKERT's two-horse watering carts. It has a cylindrical metal body holding about 1 or $1\frac{1}{2}$ cu. yds. (200 to 300 galls.) of water, a manhole through which the water is admitted, a sprinkling pipe from 6 to $6\frac{1}{2}$ ft. long, and a valve, controlled by the driver, for regulating the sprinkling, which may extend over a width of 13 ft. Other manufacturers supply carts with wooden bodies, holding 400 galls., and occasionally with a special sprinkling pipe, leaving the work to be done by a laborer who walks behind the cart and directs the water from a short piece of hose to any point on the surface that appears proper. Other carts are provided with a species of turbine which throws the water over the surface. Fig. 158 represents a hand-cart, drawn by two laborers, for use in sprinkling sidewalks.

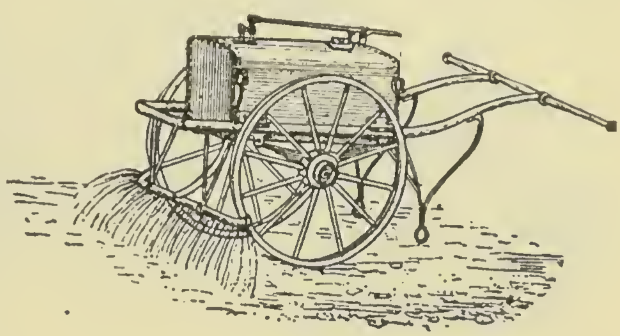


FIG. 158.

The quantity of water used by these carts varies considerably. Reckoned in gallons per 100 sq. yds., Paris requires 11 galls.; the average of many German cities, 12.1 galls.; Berlin, 13.3 galls.; Hamburg and London, 15.5 galls.; North America, 26.4 galls. and over. Usually the streets are sprinkled twice on regularly appointed days, although sometimes but once, especially with asphalt. On the other hand, the busy streets of large cities will sometimes be watered three or four times a day, and macadam as often as eight times daily. In Berlin there are only 160 days of sprinkling in the year, 120 in London, and 100 in Karlsruhe.

Each cart can be filled from 30 to 50 times daily, and their number thus determined as soon as their size is known. In Berlin the expense of labor is about 7 mills per sq. yd. annually, and the entire cost of sprinkling, including the water tax, is about 17 mills per sq. yd.

The expense of hose sprinkling is generally somewhat less than that with carts, especially where water is cheap and labor dear. Especially low rates for sprinkling are possible where salt water is

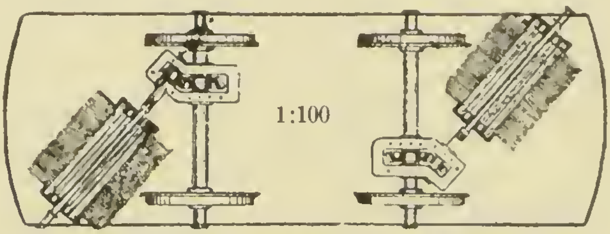


Fig. 160.—Tramway Sweeper.

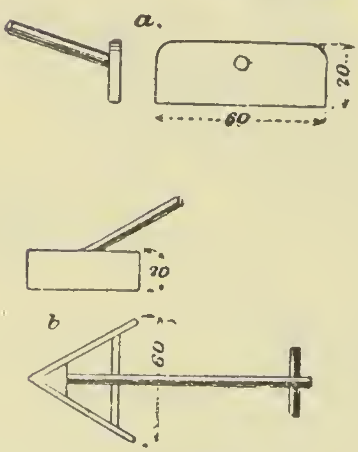


Fig. 159.

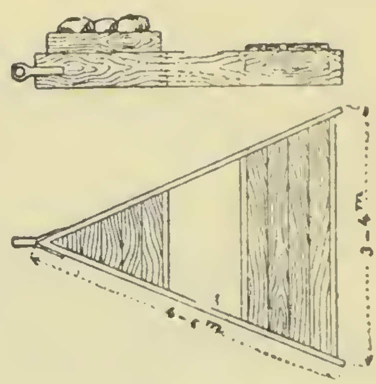


Fig. 161.

used. The thin film of salt retains dust and moisture, and thus reduces the amount of work to be done. Care must be taken that no injurious chemical results follow this practice. Several English cities have special pumps and mains for distributing salt water for this purpose.

2. *Removal of Snow.*—The demands of traffic, more imperative as the fall of snow grows larger, require the removal of part, at least, of the accumulation by private parties. The householders are everywhere required to keep the sidewalk clear, but where this is very wide (over 13 ft. in Paris), or where the number of pedestrians is small, only a part of walk need be cleared by them. The snow is thrown into the street, and must then be removed by the city. It is hardly possible in the majority of large cities to let the snow be compacted into a surface fit for runners, because

the irregular masses between the roadway and the sidewalks would prevent easy passing from the carriages or wagons to shops and houses, and the thawing of the snow would result in an unbearable nuisance on account of the closed gutters. The principal objections would come from the street railways, which require their tracks to be free from snow, and would therefore render any use of runners out of place on streets where their cars run. Therefore the street should be cleaned from house line to house line as soon as possible. But this is expensive, and it may be well to simply clear off only a part of the entire width sufficient for one or two wagons in addition to the street cars. This results in an accumulation of walls of snow along the curbing, and requires

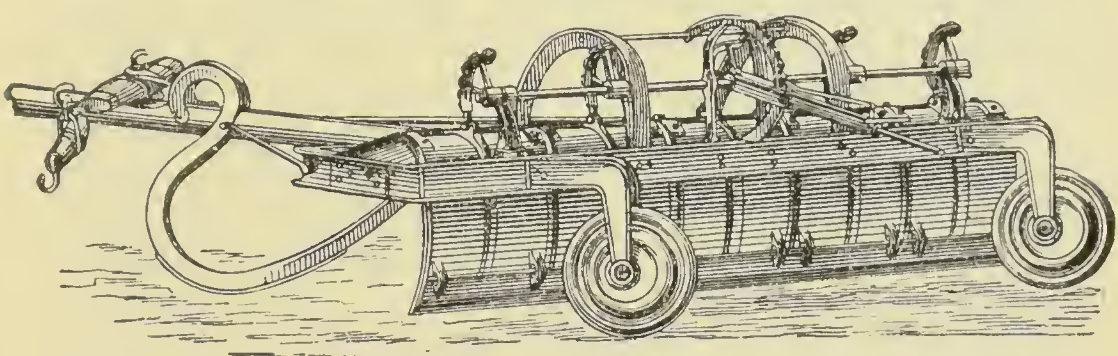


FIG. 162 – SNOW PLOW.

numerous passages from the street to the sidewalk. Such a plan is followed in many cities, and the snow is allowed to melt away slowly. Where the streets are narrow they must be completely cleared in order to permit of traffic. On account of the great diversity of local conditions, no rules for the work are possible, and the methods to be employed are those which will apparently give the best condition of the streets.

The snow is of course removed most easily soon after falling and before it has had an opportunity to become firm, but this is often impossible. The necessary tools are shovels, picks, pushers, Figs. 147 and 159, and revolving sweepers, Fig. 150, so long as the snow is not more than 4 ins. deep. Revolving brushes have been mounted on cars for the street railways, as shown in Fig. 160, where two brushes are so geared to the axles that either may be lowered across one rail, and thus be made to keep that part of the line free. By running such a car over a line in both directions, a 6-ft. strip of the street can generally be kept open all the time.

When the snow is somewhat high, plows must be used. They

are usually made of wood, in the shape shown in Fig. 161, and are loaded with stones and the attendant laborers. One horse is sufficient up to a depth of 6 ins., when two become necessary. This plow has many disadvantages: it does not adapt itself to inequalities of the surface, requires considerable power to use it, and is easily worn out. On this account DURKOOP has patented the plow shown in Fig. 162. It consists of an iron frame carried by two wheels, and a runner on the pole. The frame, which is at an angle of 45° with the pole, bears a number of curved iron shovels, each movable about a common axis or bar. These shovels cut away the snow, both moist and frozen, and force it to the side of the street. By going over the street a sufficient number of times, or by using a number of plows, the whole surface will finally be cleaned, except near the gutters. Two horses and two laborers are necessary with each plow.

The snow is usually removed in dump-carts, drawn by one or two horses. The cost, including transportation to the dumping places, is from 19 to 29 cts. per cu. yd. in Berlin and Hamburg, and is less in places, such as St. Petersburg, where the snow can be disposed of within the city limits.

If the snow can be melted at a slight expense and thus allowed to enter the sewers, the cost of removal will be reduced. No appliances for this purpose have as yet been tested on a large scale with unexpected and great quantities of snow. Heated air, steam, water, and salt have been employed. An apparatus invented by CLARKE and tested in London, melts the snow by gas flames in special pits or ditches, about 260 cu. yds. of loose snow being melted in a day in one such ditch at a cost of 5 cts. per cu. yd.

HENTSCHEL has invented a warm-water machine, consisting of a boiler, reservoir, and revolving brush mounted on trucks, and managed like an ordinary machine sweeper. The snow is simply melted and brushed away.

Salt is often sprinkled over the snow, which it melts on account of the temperature of the brine which is formed, namely 15° Cent. In Paris about 0.9 ounce of crushed salt is allowed for each inch of depth on a square yard of surface, and this amount is scattered before the snow has a chance to pack. After a few hours the slush can be easily swept into the sewer inlets and the streets cleaned with water from the mains. The economy by a systematic use of such a plan is said to be considerable, but the presence of the brine

and slush is certainly disagreeable, and is liable to cause colds and similar complaints. On this account the work is generally done at night in Paris and Liverpool; in Berlin the use of salt on sidewalks is forbidden.

3. *Regulations Concerning Slipperiness.*—Ice and mud are principally open to objections under this head. Sidewalks must generally be kept passable by the householders, since they alone can do the work with sufficient celerity. Asphalt is kept in condition by the city, and the tramways by the street-railway companies.

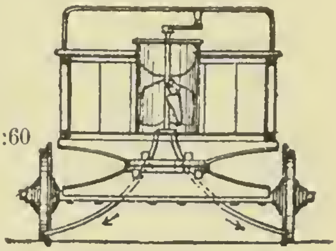


FIG. 163.—SALT SPRINKLER.

Slippery pavements are usually remedied by scattering sand or ashes, generally by hand. Wagons have been invented for the purpose, but their value is not great. One cubic yard of sand will suffice for about 3,500 sq. yds. of pavement. Since salt will melt the ice, a mixture of sand and salt may be found to work well in places, although the resulting slush is exceedingly unpleasant. On this account the use of salt is usually restricted to street railway tracks, where it is distributed from specially constructed cars, Fig. 163. These feed the material by means of a hopper, with revolving arms, through pipes directly to the rails. The amount used is governed by the speed of the arms or by cocks placed in the pipes.

CHAPTER VIII.

Quantity and Characteristics of Excrement.

Different authorities estimate the amount of fæces per capita daily from a mixed population of all ages and both sexes at from 2.82 to 4 58 ounces avoirdupois. The greater part of the figures given in the literature on the subject are based on males alone, and must be reduced by a third for a mixed population. The average composition is 75 per cent. water and 25 per cent. solids, and of the latter class 20 per cent. are of organic origin. Nitrogen is the most characteristic and important constituent, and makes up from 0.6 to 2 per cent. of the total weight.

The amount of urine per capita daily is variously estimated at from 31.8 to 45.8 ounces. From 4 to 7 per cent. of this quantity (average, 5 per cent.) is solid matter, and from 1.8 to 2.5 per cent. (average, 2) is of organic origin. The amount of nitrogen varies from 0.8 to 3 per cent., averaging about 1.

The approximate composition of all excrement per capita daily, reckoned in ounces avoirdupois, is as follows:

	Total.	Water.	Inorganic.	Organic.	Nitrogen (grains).
Fæces......	3.53	2.64	0.18	0.71	15.4
Urine......	38.84	36 9	1.16	0.78	169.8
Total..	42.37	39.54	1.34	1.49	185.2

Hence about 970 lbs. of excrement must be assumed per capita annually.

The theoretical value of excrement as a fertilizer is estimated even more variously than its quantity, since local conditions of supply and demand must be largely influential in such comparisons. Generally its value is stated at from $1 to $3.75 per capita annually; the German Agricultural Commission gives $2.82 as an approximate average. Such estimates are comparatively worthless, however, since the large amount of water present renders the use of excrement practically impossible, except near the cities and villages.

A certain percentage of the urine will always be removed in other than the prescribed ways, depending largely on the habits

of the people, and on that account the annual amount of excrement per capita which passes through the sewerage system or is otherwise disposed of may be estimated at 750 lbs., an amount which is nearly that actually measured in Heidelberg, where the excrement is removed by the cask system.

In this connection it must also be noted that a part of the waste water will become mixed with the excrement. Where water closets are employed, the water used in them per capita daily varies from 1.3 to 5.3 galls., according to a report of a committee of the German Gas and Hydraulic Engineers' Society. Investigations in Stuttgart, Karlsruhe, and Wiesbaden show that the actual amount of excrement and water to be removed annually is from 1,000 to 1,100 lbs. per capita, and similar investigations at Strassburg have indicated that this amount may equal 1,300 lbs. In this way the amount of nitrogen becomes 0.7 rather than 1 per cent. Analyses of the fresh contents of casks and pneumatic tubes show that with from 5 to 9 per cent. of solids there will be from 0.4 to 0.84 per cent. of nitrogen.

The character of human excrement changes quickly. Within 24 hours dangerous gases, carbonic acid and ammonia, will have been given off amounting to 0.1 per cent. of the total weight of the mass. The liquids in cesspools and retaining basins show quite different results on being examined chemically, according to the decomposition that has taken place. The limiting values of solid matter are 2 and 6 per cent.; of nitrogen, 0.24 and 0.66 per cent.; the average being 0.4 per cent.

The character and influence of excrement has been well shown by Dr. Emmerich by experiments with animals. On injecting fresh urine containing no bacteria into the blood, no evil consequence could be noticed; while fæces, which are partly decomposed on leaving the system, had to be diluted 20,000 times in order to become harmless. Every kind of excrement was fatal after standing a few days and had taken up bacteria.

The different conditions under which excrement occurs in sanitary engineering practice are as follows, reckoned for each inhabitant per year:

Condition.	Quantity, lbs.	Solids, per cent.	Nitrogen. Per cent.	Nitrogen. Lbs.
Fresh, total amount	970	7	1	9.7
For removal in sewers	880	7	1	8.8
For separate removal, fresh	1,100	6	0.7	7.7
" " decomposed	1,100	4	0.4	4.4

CHAPTER IX.

Removal of Excrement.

There are three ways in which privy vaults are cleaned—by manual labor direct, by pumps, and by pneumatic apparatus.

1. *Manual Labor.*—In this plan laborers either descend into the vaults and remove the contents by handing up buckets, or the removal is effected by buckets on long handles, with which the contents are scooped out of the vault without entering it.

The first method may be dangerous in badly ventilated places, and various remedies have been proposed, such as pumping in air or disinfecting several hours before the work begins. The presence of dangerous gases can be detected by lowering a light, which should not go out. In spite of its cheapness—the profits often exceed the expenses—since the peasants do the work themselves, and the lack of responsibility thrown upon the town authorities, hand removal is not adapted to cities, on account of the time consumed, the uncleanliness, and the odor attending it.

2. *Pumps.*—A combined suction and force pump, driven by cranks, is mounted on wheels and connected by pipes with the vault on one side and the receptacle on the other side. The latter is usually a cask of wood, or, better, iron, mounted on wheels, holding from 320 to 790 galls., and provided with a glass water-gage, air valve, manhole, and cocks for connection with the pipes. Where the pumps must be stationed some distance from the vaults, the connections are formed with thin iron pipes and rubber hose.

The suction pipe ends in a sieve to hold back the solid matter, which would injure the machinery. For a like purpose the contents of the vault are sometimes diluted with water or stirred, although the more simple plan would be to remove the solid portions subsequently. Under any system, the pumps will be quickly worn out. To this defect must also be added the long time required and the vile odor. Hence this method has been replaced in many cities by the following:

3. *Pneumatic Method.*—In this plan the cask by which the

excrement is removed is first exhausted of air and then connected by a pipe with the vault, the contents of which will be then trans-

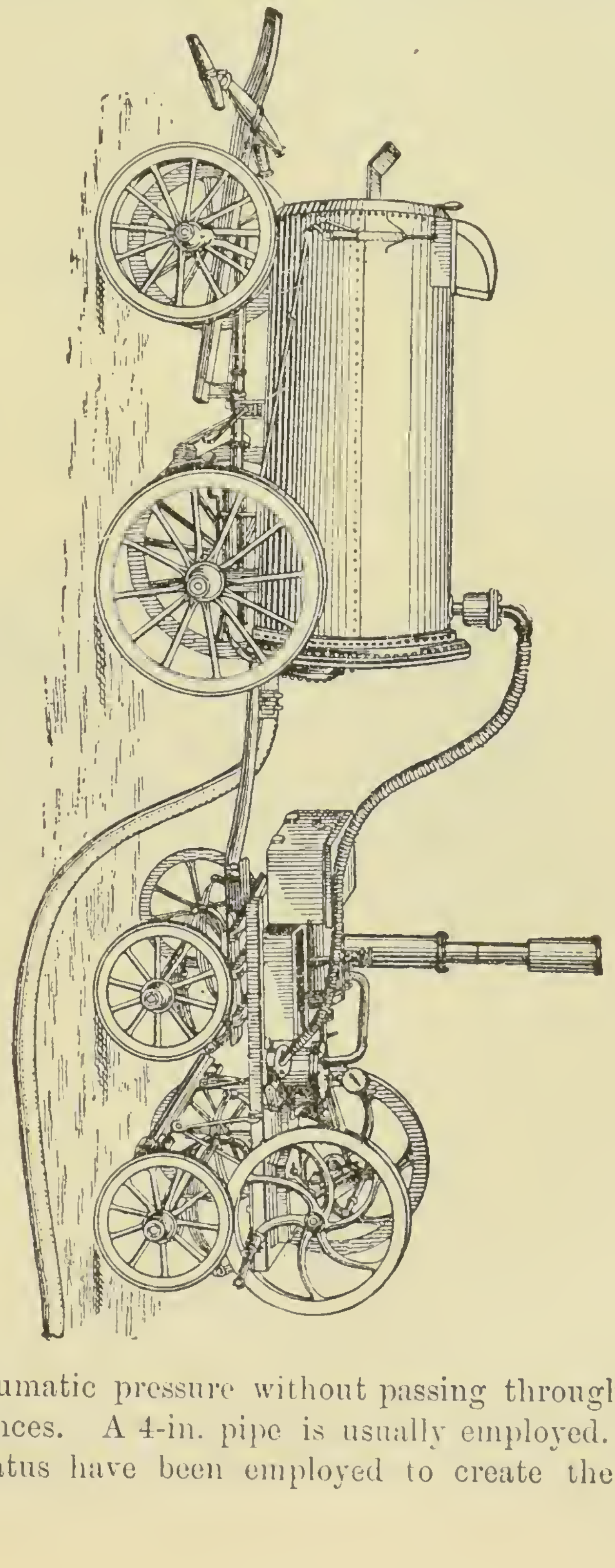


FIG. 164.—PUMPS FOR CLEANING CESSPOOLS.

ferred by pneumatic pressure without passing through valves or similar appliances. A 4-in. pipe is usually employed. The following apparatus have been employed to create the necessary vacuum :

a. Portable pumps operated by one to four men. Fig. 164 represents a form driven by cranks, and Fig. 165 one operated by levers. The air is sucked from the cask, forced by the pumps under a coal fire, and escapes in a fairly pure condition from the chimney. The time necessary for this process is considerable, being from 4 to 10 minutes for each cask, and the vacuum is not sufficient to remove the semi-fluid sediment in the bottom of the vaults.

b. Portable Steam Pumps.—The fires are usually fed with coke, since it gives off little smoke. The pumps are usually of 2 or

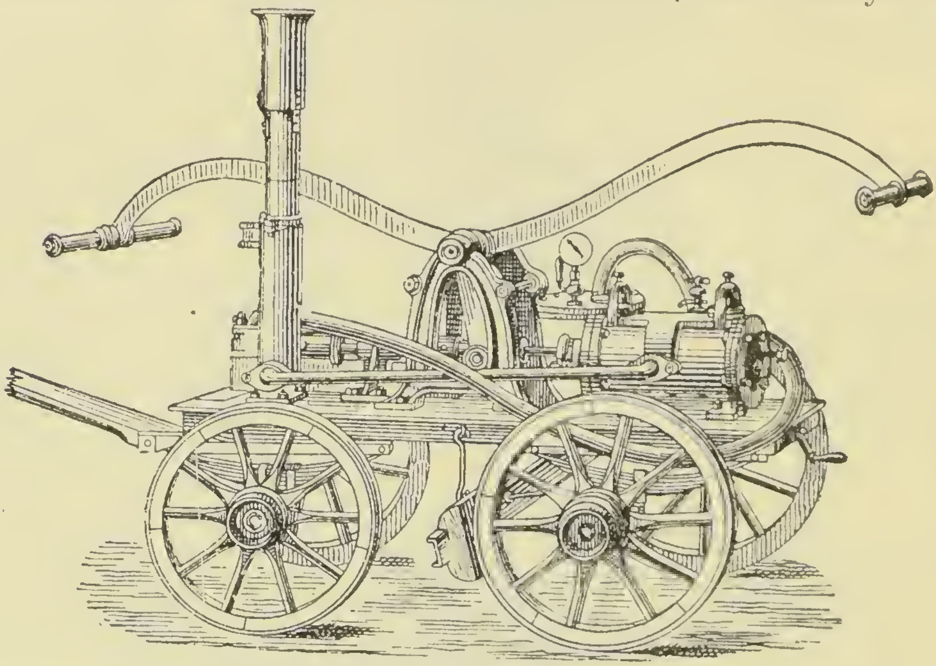


FIG. 165.—CESSPOOL PUMP.

3 horse-power, worked with 30 to 60 lbs. pressure, and require from 110 to 154 lbs. of coke daily. It requires only about 2 minutes to create a vacuum of $\frac{1}{3}$ to $\frac{1}{4}$ of an atmosphere in an iron cask of 660 galls. or 88 cu. ft. capacity. This reduction of pressure is sufficient to drain a vault of nearly all its contents, even when they are quite thick, and any further reduction is a waste of fuel and time. Five men will fill from 50 to 70 casks with this machine daily. The air that is pumped from the casks is forced through the fire, causing an artificial draught that is highly beneficial. By properly adjusting the valve gear all noise from the escaping steam is avoided. This apparatus is extensively employed in Strassburg, Metz, Karlsruhe, Munich, Hannover, and several other places.

c. In the LENOIR and SNEITLER system, an iron reservoir is mounted on the same frame with the pumps. It is filled with the contents of a vault by being exhausted of air in the manner just indicated. The valves of the pumps are then changed for pressure service, and the reservoir is emptied into the casks for removal by forcing air into it again. The advantage gained lies in the fact that casks in which the matter is removed need not be air-tight as in the TALARD system, described under *b.* The double duty required of the pumps and the consequent loss of time are decided drawbacks.

d. Steam Ejectors, KELLER-PHILIPPOT system.—In this system the steam consumption is so great that the boilers must work under a pressure of 100 to 130 lbs., in order that the ejector may have the 45 lbs. pressure necessary to fill a series of casks continuously. This requires about 330 lbs. of coke daily. The air absorbed by the ejector from the casks is forced through a reducing valve into the fire-box, or else returned to the vault through a second pipe, where it serves to agitate the contents. Although the apparatus, arranged like a steam injector, is more simple than an ordinary pump, and has no moving parts, nevertheless it possesses disadvantages, such as a dangerous boiler pressure to be carried in streets, and a large fuel consumption for the work done. The system is employed in Strassburg and Muelhausen.

e. The casks are exhausted of air outside the city at the dumping places after the contents of the previous trip have been discharged. This may be done by stationary pumps, but usually one of the two following methods is employed: The casks may be filled with live steam, which will cause a partial vacuum on condensation, as is done in Muenster and Bremen; or the casks may be filled with water and then placed in a chamber where a vacuum is maintained. On allowing the water to run out, the casks will be free from air. If the air inlet of a cask is connected with a 33-ft. pipe closed at the upper end and the water is then allowed to run out, a vacuum can also be obtained. This system is employed in Turin and Milan. The empty casks are then taken back to the city. The advantages of this process lie in the short time required for the work done within the city, and the escape of the foul air only outside the city limits. On the other hand, absolutely air-tight casks are necessary.

f. A Frankenthal company (KLEIN, SCHANZLIN & BECKER)

has introduced a system in which each cask is supplied with a small pump. The motive power is furnished by the horses in drawing the casks between the city and dumping places. For this purpose one of the cart wheels is keyed to its axle, which in turn is geared to the pump. While the wagon is in motion the pump is also moving, unless thrown out of gear purposely. Beside the advantages mentioned under *e*, this system has a special claim for preference from the fact that the casks are emptied of air without manual labor or delay. The cost, however, is somewhat high.

The cost of the removal varies greatly. The exact figures can only be determined when all the work is done by municipal laborers; Stuttgart is the only large city where this is the case. Hence the comparison is usually restricted to the taxes which the householders pay for the work, which range from 0 to 61 cts. per 100 galls. The removal is gratis in Krefeld, Wiesbaden, and Strassburg; in the majority of small German cities it is from 5 to 19 cts., and in the larger places it may rise to 43 cts.; 61 cts., the maximum, is paid in Paris.

In the majority of cities the tax is the same for all houses—a simple plan for the authorities, but only right where the style of architecture is uniform. The charges should be graded according to the difficulty of the work, as is done in some cities. Vaults which are easily accessible are more quickly emptied than others that require a long line of pipe to the pumps and casks. In Dresden the charges are divided into 5 grades, and range from 30 to 48 cts. per 100 galls., according to the length of pipe necessary. The average in that city is 37 cts. Such a regulation tends to have the vaults in new buildings located in places that are easily reached, which is a desirable sanitary precaution, and has led to the introduction of fixed pipes leading from the vaults into courts, or even to the street, by which the excrement is removed without uncovering the pits. Such fixed pipes may lead to a number of vaults. In some places an additional tax is levied where water closets are connected with the vaults, since the excrement then has a smaller commercial value. In Leipzig the regular prices are doubled, and in Wiesbaden the tariff is raised 9½ cts. per 100 galls.

There is no material save iron, which is expensive, that will prevent the escape of the contents of privy vaults and cess-pools. All other materials are subject to change, owing to their alternat-

ing contact with air, water, and in some cases acids. The vitiation of the air is a still worse feature of vaults, and their contents have a smaller value after standing for a short time than when fresh. Both facts call for as frequent cleaning of such places as possible, while the disagreeable features of the work tend to cause delays. Stuttgart has passed a regulation requiring the cleaning to be done once in four weeks in ordinary houses, and more often in large establishments. In all other cities the work is done on application of the householder, the contractor being allowed from one to two weeks, within which time the vault must be cleaned. A systematic cleaning by streets is much more economical than this plan, and is in force in Stuttgart, where the cost of the work when done in regular order is 35 cts. per 100 galls., or 46 cts. when done on application. The Prussian Commissioners recommend a more frequent cleaning when water closets discharge into the vaults than when the closets are all dry, on the ground that in such cases there is more leaking through the walls into the surrounding soil.

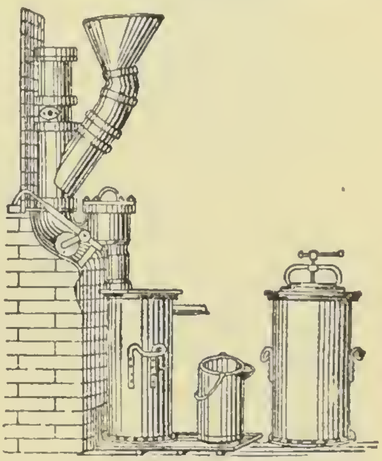


FIG. 166.

All of these drawbacks have led to the use of small, movable receptacles, which can be easily and quickly emptied.

Small open pails holding from 5 to 10 galls. and placed directly under the privy seats are extensively employed in Bremen, Groningen, and other places. Such a system is directly opposed to all sanitary demands, and the appearance of the pails standing on the sidewalks before the carts arrive is extremely offensive. A slight improvement is made in Kiel, Rostock, Emden, and Amsterdam, where the pails are provided with tightly fitting covers. But they remain as unpleasant in the house and are as bad, from a hygienic point of view, as the vaults.

The system is satisfactory only when soil pipes lead from the closets to the pails, and the gases from the latter are prevented from escaping in the houses and on the streets. Wood is a less suitable material than iron for these pipes, being harder to clean and less durable. The Heidelberg pails, Fig. 166, are from 15 to 18 ins. in diameter, 31 to 35 ins. high, 23 to 29 galls. capacity,

and weigh from 75 to 100 lbs. when empty and 290 to 330 lbs. when full. They are painted or galvanized annually. The largest pails are used in Augsburg, where they are made of beechwood, and hold from 47 galls. in small houses to 79 in large.

The connection between soil pipe and drain is often only loose, simply a funnel or similar contrivance. This would be sufficient if the pail chamber was thoroughly ventilated by a continually warm ventilating pipe, as required in Goerlitz. Where this is not

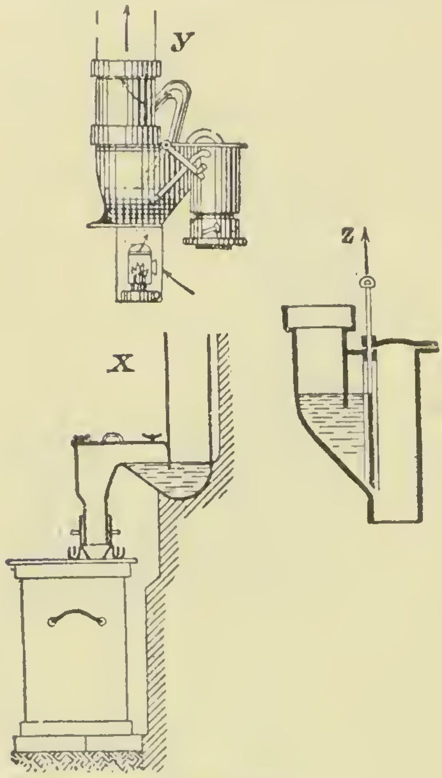


FIG. 167.

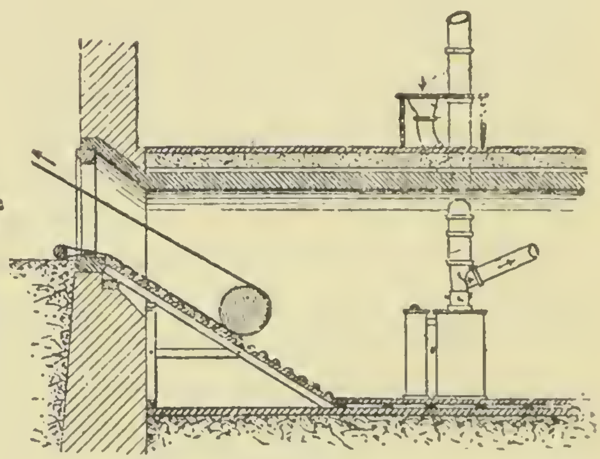


FIG. 168.

the case the system has few advantages over open pails, although extensively employed, especially in the country. An air-tight connection which can be quickly removed, usually held by a bayonet catch 2 to 4 ins. long, is to be preferred, and may be regarded as the present standard. The escape of gases is prevented in four ways, as follows:

a. The soil pipe is directly connected with the lid of the pail, and prolonged upward through the roof as a ventilator. This method may suffice where the pails are removed every other day and decomposition is not allowed to take place to any great extent within the building.

b. The soil pipe is arranged as in *a*, but has a water-trap con-

nection with each closet in order to prevent the escape of gases from the pails into the house.

c. The soil pipe has a water-trap connection with the pails, as shown in Fig. 167. A prolongation of the soil pipe as a ventilator is desirable, but not so necessary as in the above cases. In Heidelberg, where the closets are all on the ground floor, no extension is provided. In order to clean the trap and protect it from frost various plans have been adopted, such as a movable lid in the LIPOWSKY system, shown at *x*, used in Heidelberg, or a movable tongue, shown at *y*, and employed in Weimar in the SCHMIDT system. The heating appliances used as a preventative measure against freezing do not cause any ventilation. The FRIEDRICH system, employed in Leipzig, is shown at *z*.

d. The soil pipe is closed above the upper closet and is connected directly with the pail. A special ventilation pipe, see Fig. 168, leads from the soil pipe just above the pail to the roof, and is warmed by its proximity to a chimney or by a special gas jet at its foot.

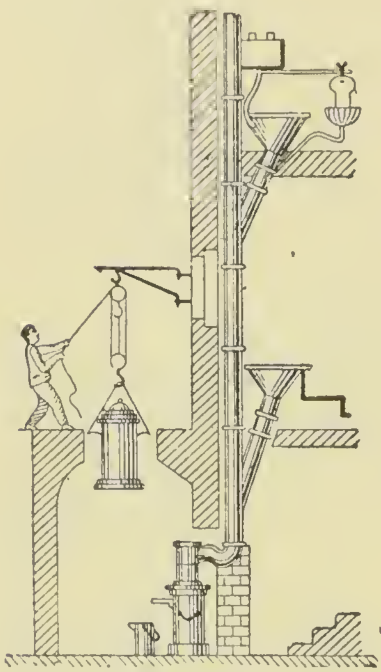
The best systems, especially as regards the gases in the soil pipe, are those falling under *b* and *d*, yet the others have proved satisfactory where the pails are frequently changed. The employment of water flushing also influences the choice. This is generally practicable, but increases the cost of removing the excrement; when it is not done the methods *b* and *c* are questionable. Everything considered, the last system is probably the best.

As a safeguard against overflow, a small drip pipe should be provided, as shown in Fig. 166. It should be guarded by a sieve within the pail and empty into a small bucket or a second pail. The second plan would be better as preventing evaporation, but might lead to the destruction of the water seals, owing to the sudden escape of a large amount of air from the pails to the soil pipe, Where a standard pail is not of sufficient size, several might be coupled, as shown in Fig. 168, the last being provided with an open drip pipe.

The pail chamber should be constructed with solid walls and a water-tight floor; water taps and good drainage are desirable, as well as a means of heating. The pails should stand upon wooden platforms to prevent rust and decay. The chamber should be designed only after thoroughly considering the probable effect of the heat of summer and the cold of winter, and be so situated that

the pails can be easily removed. Generally they are in the basement, when suitable means of removal must be supplied. Sometimes the pails are rolled up a skid, as shown in Fig. 168, and sometimes pulled up by a tackle, as in Fig. 169. Oftentimes they are carried out by two men by bars run through the handles, Fig. 173, when the distance is not great.

The further transport to the gardens or fields may be done in shoulder pails, Fig. 170, holding only a small quantity, or in larger receptacles mounted on wheels, Figs. 171, 172. When the latter method is employed the pails should be supported near their center



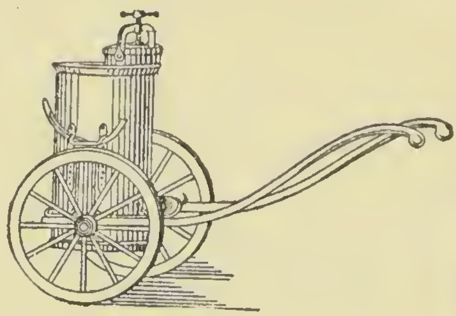


Fig. 171.

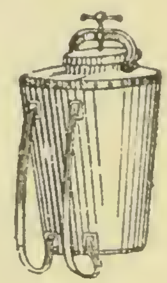


Fig. 170.

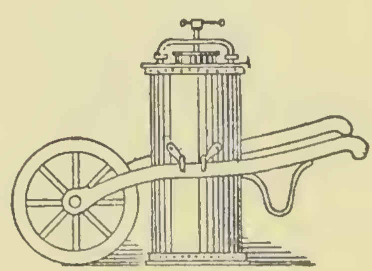


Fig. 169.

Fig. 172.

of gravity, thereby allowing the contents to be poured out easily. In cities, wagons carrying a number of pails are necessary. Ordinary trucks are not suitable for the purpose, since they must be loaded by skids. Low bodies, on which the pails can be easily lifted, are much better. One horse will draw from 10 to 12 standard pails, but larger loads are easily handled by the wagons used in Heidelberg, shown in Fig. 173. These are provided with curtains, which hide the load from the sight. The Manchester wagons also carry a receptacle for the dry pails, a great convenience for the residents.

In large buildings, where the quantity of excrement is great, casks mounted on wheels or even special wagons are used in place of pails. The receptacles shown in Figs. 174 and 175 hold from

50 to 100 galls., and have inlets and outlets controlled by valves and a glass water gage. Where still greater capacity is required, a large iron tank mounted on 4 wheels is usually employed. These sometimes hold as much as 775 to 800 galls., and are provided with two or more inlets and a manhole, as shown in Fig.

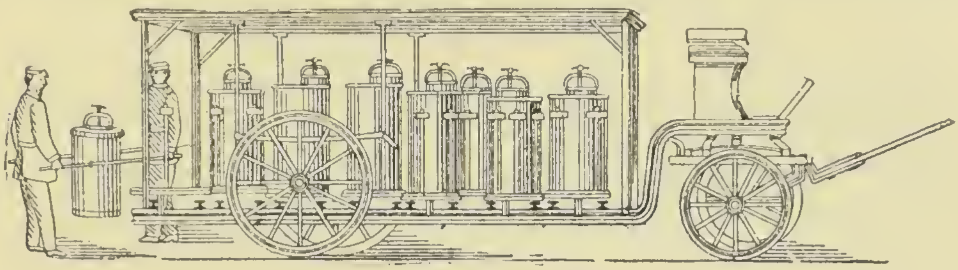


FIG. 173.

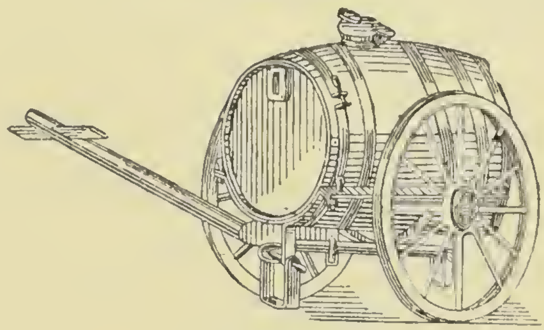


FIG. 174.

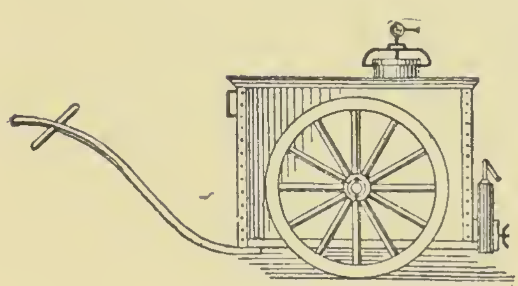


FIG. 175.

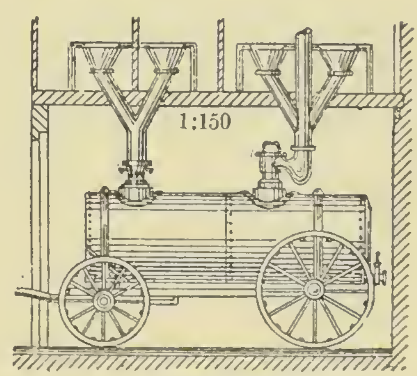


FIG. 176.

176. By giving the tank a slightly conical form all its contents will readily flow from the outlet.

In removing a pail, it is of course necessary to have another to take its place. They should be thoroughly cleaned after being emptied, and disinfectants may be sometimes used advantageously in this work.

The interval between successive removals varies greatly in different places. Where small pails are employed they should be changed every third day at least. In Kiel, Rostock, and Emden

the removal takes place twice every week. In Heidelberg, where the service is exemplary, the pails in houses containing from 15 to 20 persons are changed every 2 or 3 days, with fewer persons every 3 or 4 days, and in crowded dwellings daily. The average time is 3 days; in Goerlitz, 5; in Augsburg, Weimar, and Rochdale, 7; in Bergen, 14; although frequent disinfection occurs in the interim.

The cost of pail removal is met everywhere by taxes or fees. In many places the contractor receives a bonus from the city in addition to the usual fees, in order to make up for the somewhat greater labor required by the system. The fee for removing each small pail once is $2\frac{1}{2}$ cts. in Koenigsberg, $3\frac{1}{3}$ cts. in Kiel, $7\frac{1}{2}$ cts. in Rostock; standard pails, 5 cts. in Heidelberg and Weimar. The total cost of the system, including the bonus from the city, averages between 37 and 63 cts. per capita annually.

Although the work can be carried out more easily with a large than a small number of pails, yet there is a limit beyond which the system will give rise to heavy transportation expenses to the dumping grounds, and to an interference with ordinary traffic. Hence it is best adapted to places of moderate size, and is unsuited for large cities. The English cities Manchester and Rochdale are so arranged that the removal takes place from the rear of the houses through small streets and alleys, and does not occur very frequently. In the German cities mentioned as using the pail system, only a part of the houses are fitted in this manner. Gratz is the only place where its use is universal, and there the service is by no means commendable. Nuremberg adopted it only to be again abandoned.

CHAPTER X.

Removal through Pneumatic Tubes.

The disadvantages attending the storage of excremental matter in houses and the cumbrous appliances employed in the pail system led Liernur to invent a network of underground tubes through which this matter is removed by pneumatic methods.

At a suitable place, as low as possible, without the city, is a central reservoir, from which a system of main pipes lead to a number of district reservoirs. The latter are scattered over the whole city, and are entirely separate from one another. From these district reservoirs a series of street pipes radiate in every direction, and to these are connected the house pipes. The size of the districts is such that the longest street pipe will be about 1,000 ft., and connect with 60 houses, while the district reservoir must be large enough to contain all the excremental matter of a day from its district, which usually is from 37 to 50 acres in extent, and contains from 2,000 to 3,000 inhabitants. Each house pipe must be of sufficient capacity to contain the daily matter of the house to which it is connected, see Fig. 177, or at least the greater part of it, the remainder passing into the street pipe.

All pipes and reservoirs are constructed of iron, must be air-tight, and lie below the frost line. Each district reservoir must be connected with the main and street drains by valves, the stems of which run to the surface and are operated like water hydrants. The pipes are generally $5\frac{1}{4}$ ins. in diameter.

The air pump at the central reservoir, calculated by assuming 0.25 horse-power for each acre, according to the inventor, maintains a vacuum of 11 lbs. per sq. in., or three-fourths of an atmosphere at this point during the entire period of operation. This diminution of pressure also occurs in the district reservoirs as soon as the valves are opened, and the same thing also occurs when the street pipes are connected. This reduction of pressure causes the matter in the house pipes to be sucked through the street pipes to the district reservoir. The work is performed by emptying one street pipe at a time, the vacuum in the reservoir being

renewed after each discharge. The district reservoirs are emptied into the central basin in the same manner, either directly or through each other. The entire manipulation of a street pipe requires only 2 or 3 minutes; and a district reservoir can be emptied in 10 to 20 minutes, so that the entire excremental matter can be removed daily, although in Holland from 1 to 3 days elapse between successive removals.

All the house pipes connecting with the same street pipe become empty simultaneously, as otherwise air would enter the network through the first empty tube, and hinder or prevent the removal of the remainder of the matter. This danger was formerly met by a rubber ball floating on the top of the liquid in a chamber above the siphon, as shown in Fig. 105. After the matter has been sucked away, the ball is pressed down against the lower seat and prevents any air from entering the vacuum pipes. This theoretically correct action was only imperfectly obtained in practice: the exclusion of the air was imperfect, and occasionally the ball stuck to the lower seat and failed to rise. Hence its use was discontinued, and the arrangement shown diagramatically in Fig. 178 has been adopted. It is essentially a large water-trap, with an inclined arm from 20 to 50 times as large as the upright section. From a very full trap or sack the discharge is quicker than from one containing a smaller amount of matter, but the difference is not sufficient to cause all the pipes to become empty simultaneously, and the LIERNUR system never completely removes all the contents of the pipes. A complete discharge can only be obtained by connecting each house pipe with the street by a valve, and opening and closing these valves one after the other down the whole length of a street.

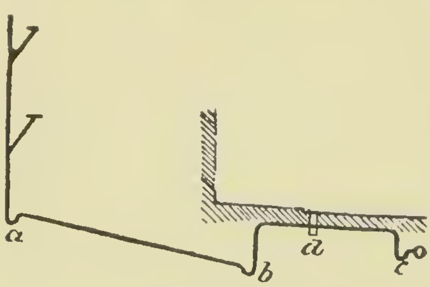


FIG. 177.

Each closet must have a water trap connection with the soil pipe, which should be prolonged to the roof as a ventilator, as a safeguard against the matter remaining in the house pipe. A less suitable plan is to have a water trap at the foot of the soil pipe or at its entrance to the house, and thus keep the gases shut in the pneumatic tubes. The objection is that the gases from the soil pipe are allowed to enter the dwelling-rooms unchecked. LIER-

NUR proposes, as the most satisfactory plan, the arrangement outlined in Fig. 177. There are three siphon traps—one at *a* at the foot of the soil pipe, one at *b* at the house wall, one at *c* at the connection with the street pipe; a valve at *d* is provided for the purpose of shutting off the house for repairs.

In large plants the main pipes might consist of two tubes laid side by side, one being a suction pipe for producing the vacuum and the other a transporting pipe through which the matter is removed. The latter should not have a uniform grade in large plants, since the pressure of the air in such a case might separate the "piston" of excremental matter in front of it and result in only a portion of the total quantity being drawn to the central reservoir. Hence the transporting pipe should have several abrupt descents of 3 ft. or so, at the foot of which the matter is again united and the air concentrated. The same result may be obtained by employing a number of small secondary reservoirs, from which the flow begins anew.

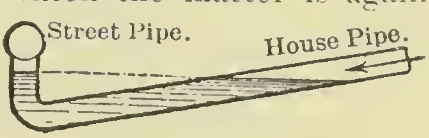


FIG. 178.

If a central reservoir is dispensed with, each district reservoir, or even each house, can be connected with portable pumps, and its contents thus removed. Main pipes are entirely wanting in such a case. As compared with privy vaults, the system offers the advantage of daily removal, and the house is entirely free from disagreeable operations, but there is then need of a large number of carts. In places where only a few districts would be needed, the system may deserve consideration. It was employed in Amsterdam until 1884, where some 30,000 residents were divided into 6 districts, and 30,000 more were served in a house to house manner. Since then the system has been more centralized.

The LIERNUR system has been adopted in a barrack at Prague and in parts of Amsterdam, Leyden, and Dordrecht. From the first installation on, the connection between the closets and the pipes was by means of a so-called excrement seal, the last discharge forming the seal, and giving rise to highly offensive odors as well as tending to stop the pipes. In the barracks this would give rise to no great difficulties, but in the Dutch cities large quantities of water are discharged into the pipes, partly to keep them clean and partly to be easily rid of the waste water. In some places as

much as 1.3 galls. per capita come from the closets daily, although the average is only 0.37 gall., as already noted; the mean of all the Dutch LIERNUR systems is 0.63 to 0.74 gall. Hence the number of water closets should be taken as a basis of calculation, and the consumption of water be limited to from 1 to 1.3 galls. daily per capita or even 1.6 galls. in order to allow for a future increase of the numbers using the closets.

The removal of excrement by pneumatic tubes insures great safety against pollution of the air and contamination of the soil. The iron construction prevents serious leakage, and disease

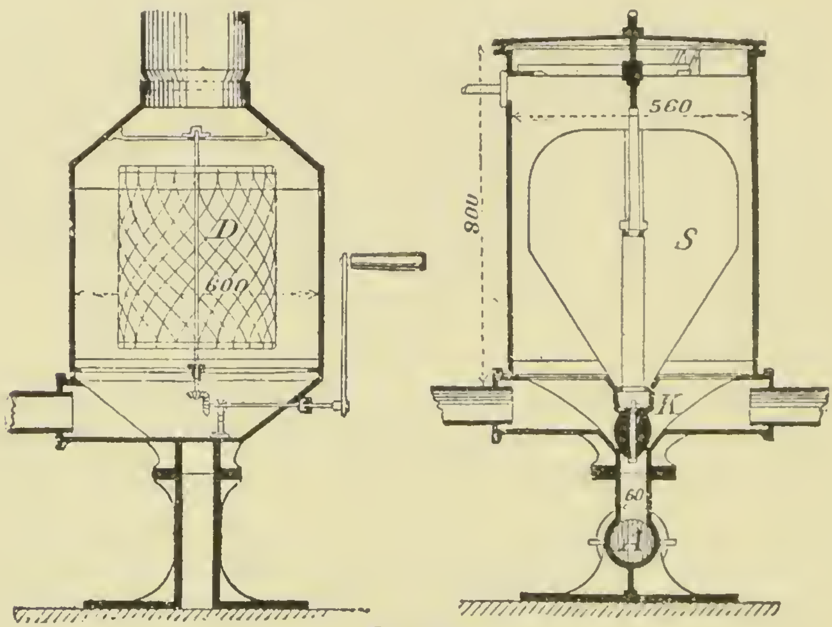


FIG. 179.

germs are carried along the pipes to the reservoirs, from which all the air is discharged under the grate of a furnace or boiler, and the germs are therefore burned. However excellent the system appears in theory, in large plants it fails practically on account of the complicated apparatus. In Amsterdam the removal costs 20 cts. per capita annually in districts with fixed pumps; where house to house service prevails, the cost is 43 cts.

The pneumatic principle has been experimentally employed by BERLIER in one of the Paris barracks. The excrement passes from the closets to a receiver, Fig. 179, placed in the basement and containing a cylinder of wire with large meshes, which retain the large substances that should not enter the closets. The matter then passes through a pipe to a discharger, with which several receivers can be connected. An india-rubber ball,

K, closes the lower conical part from the pneumatic tube, *A*. The ball is connected to a float, *S*. When the liquid has reached a certain level, the float and ball are lifted and the contents of the chamber escape, the current bearing with it the matter clinging to the basket, *D*. The process is repeated automatically and may be continuous if the liquids are present in sufficient quantities to keep the discharge always nearly full. The network of the pipes can be laid in the same manner as in LIERNUR'S system.

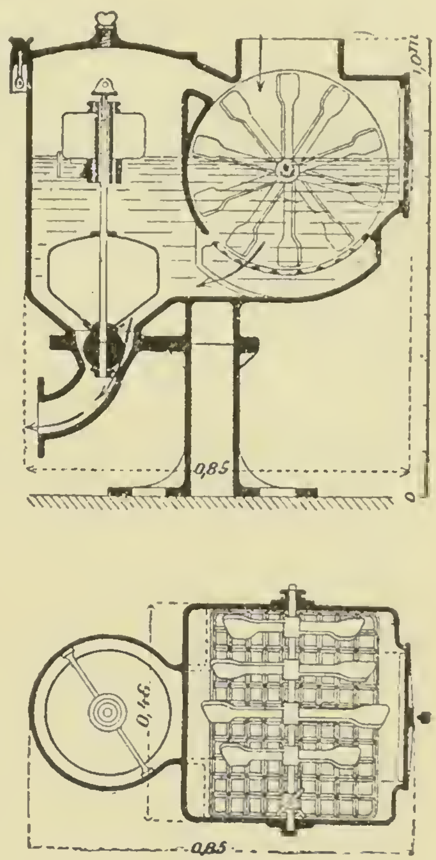


FIG. 180.

Although this plan offers the advantages of separate house connections and an automatic regulation, it has the following serious defects:

1. The wire basket must be revolved several times a week, in order to keep the meshes open.

2. The basket must be removed and cleaned inside the house.

3. Considerable basement room is required, and the house must be visited by laborers.

4. Evaporation will take place through the hole in the lid of the discharger, which is necessary for a proper working of the apparatus.

5. The ball and float may become fixed by deposits of solid matter.

Experiments still require to be made to show the force of these objections with large plants; they have been partly met in the new apparatus of BERLIER, in which the receiver and discharger are in the same chamber. The former is horizontal and discharges through a grating, as shown in Fig. 180

CHAPTER XI.

Financial Considerations.

The excremental matter of a city is generally the property of the city, or the contractor who removes it, where public removal is obligatory. But it is often desirable to allow the owner of a vault to form a private agreement with the contractor to have the contents of the vault removed to land belonging to its owner. In Karlsruhe this work is paid for at the rate of 21 cts. per 100 galls. and haul of 1.243 miles. Some return should be received for the very considerable amount of fertilizing matter in the excrement. The land necessary for utilizing these fertilizers may be calculated from the fact that from 25 to 70 lbs. of nitrogen per acre are required annually. These amounts correspond to from 4 to 9 persons in case the matter is fresh, as is the case with the pail system, or from 6 to 16 persons when it reaches the fields in a partly decomposed condition.

In some places an agreement has been made with the farmers by the terms of which they receive the pails on their fields in regular turn or store the contents in private reservoirs or in tank wagons. The transfer to the latter can be most easily made by running the city carts upon a raised platform below which the private wagons are placed; iron pipes and funnels make the transfer a very easy and quick operation. Since the advent of winter puts a stop to the use of fertilizers, the sewage must be stored during this season in private or public reservoirs. Those employed in Strassburg and Karlsruhe are large enough to contain the excremental matter of three months. It is advantageous to have several reservoirs at different points outside the city limits; they should be located so that the offensive odors which arise will not create a nuisance, and should be constructed of water-tight masonry with a wooden or arched top, through openings in which the pails from the city may be emptied.

The use of carts is only economical up to a certain length of haul, beyond which steam tramways are more suitable. Stuttgart has developed the latter system most completely of any German

city, being compelled to do so by the rapid growth of the place and the hilly character of the surrounding country. The tank carts are emptied by tubes at a special station into cars carrying 3 wooden tanks, holding, in all, 790 galls. At the country stations the private parties may receive the matter in their carts or it may be run off into reservoirs and stored. The repeated transfer is cheaper under such topographical conditions than the long transportation in wagons would be. In level places it might be better to remove the matter in the same tank from the city to the reservoir.

The steam tramways in Munich, Dresden, and Leipzig are arranged on a somewhat different plan. In order to diminish the weight as much as possible, large tank cars holding 2,640 galls. are employed. The city tanks are emptied by the same pneumatic apparatus used previously to fill them. In these cities the tramways are already from 40 to 56 miles long. In Stuttgart more than half the excremental matter is removed in this manner.

The proceeds from direct sale of the matter depend upon the amount of dilution it has received and the time it has stood, upon the distance it must be hauled, and upon the competition of other fertilizers and the general demand for them. Hence it is not strange that the price of excremental matter at the reservoirs varies from 13 to 57 cts. per 100 galls., the latter amount being sometimes paid in Strassburg and Stuttgart.

When the peasant receives the matter within the city he naturally pays less—38 cts. in Strassburg, 27 cts. in Mainz—as is also the case when his carts are filled directly from the railway cars, as in a number of Baden country places, where the price ranges from 28 to 44 cts. In Mainz the price for delivery at the fields is 67 cts.

The proceeds from the pail system are generally not greater than the above figures, being largest in Goerlitz, 48 cts., and Rostock, 56 cts., although the fresher condition of the matter makes it really more valuable. But it cannot always be immediately applied, and in such cases decomposition soon reduces its original value. The pneumatic tubes deliver the matter in a very fresh condition but greatly diluted. In Holland, from 14 to 48 cts. per 100 galls. is paid, the average being about a half of the proceeds from the pail system. German prices cannot be given, but such matter is sometimes refused by the peasants.

The sale is always attended with risks, and in some places, when no persons apply for the matter, it is thrown into the water, as in Graz, Amsterdam, and Paris. Purchase of land for cultivation with excremental matter is not advisable for cities, on account of the extent of the work. But land belonging to the city might be leased with the understanding that a certain amount of the excrement is to be used upon it by the tenant.

In order to relieve the municipal authorities of all the difficulties attending the disposal and sale of fæcal substances the whole work is usually let to a contractor. Hence the net earnings are difficult to determine. When the work is done by the city, the figures are easily obtained, although even then part of the labor, such as pumping or carting, may be done by contract. The account for Stuttgart for the financial year of 1885–86 showed that the total expenses per capita were 62 cts., and the total proceeds 37 cts., leaving 25 cts. to be paid by taxation. The city called for 45 cts. per capita as a tax, so that the accounts showed a nominal profit of 20 cts. as far as the disposal accounts went, although the householders were not able to show any such profit. In Manheim, the entire outfit belongs to the city ; in 1887 the proceeds there were 57 cts. and the expenses 71 cts., the difference being partly met by a tax of 11 cts., which has since been raised.

From 1871 to 1889 the pail system in Heidelberg was managed by an association of the householders ; since then by the city. From 1881 to 1886 both expenses and proceeds averaged 61 cts. per capita annually, the latter consisting of 20 cts. for the matter and 41 cts. paid by each person (the latter sum being the cost of the system to members of the association). The city gave a bonus for covering the additional expenses caused by certain municipal regulations regarding the dumping places.

The Baden barracks present the only example of places actually receiving a profit from the excrement, which is partly due in their case to the fact that the matter is carried in a fresh condition directly to the fields. The peasants sometimes pay for it a sum corresponding to 62 cts. per capita annually.

When the entire work is done by contract the expense to the householders is simply the fee they are required to pay. The city loses the interest on the sum invested in the appliances and buildings lent to the contractors. Sometimes, but rarely, the removal is

done gratuitously. Some contractors apparently make large profits, such as the Dresden Removal Co., which pays 9 per cent. dividends, while others apparently work at a loss. The city might give out short contracts and supply all the tools and appliances, or require the contractors to pay into its treasury all profits exceeding a certain percentage. Under such conditions the municipal authorities would be sure of receiving some returns if the disposal was very profitable.

CHAPTER XII.

Special Treatment of Excremental Matter.

The drawbacks attending the sale of excremental matter are eliminated when the portions which are of value to farmers are separated and reduced to a form adapted for transportation and use. The poudrette, the usual product of the concentration, should be delivered in such a condition that it can enter into competition with existing fertilizers. Numberless inventions for this concentration have been brought forward from time to time, all of them based on one or more of the following processes: Evaporation, concentration in a filter-press, chemical treatment, or mixing with other fertilizers. No description of these processes will be given, as they have all proved impracticable or too expensive. Rawlinson and Read stated in one of their works that no method of preparing fertilizers from city refuse, either with or without the addition of chemicals, has paid for the cost of the process. Since this opinion was given three new methods, described below, have been introduced:

1. Podewils treats the excrement with sulphuric acid to fix the ammonia, and then saturates it in an agitator with smoke from a fire, whereby it is partly evaporated and deodorized. The mass is then completely evaporated in shallow pans, placed eight deep, one above the other, in a chamber through which circulate the heated air and flames from a fire at the bottom. Recently vacuum chambers have been employed in which boiling takes place at from 150 to 185 degrees Fahrenheit. The fæces come in contact with the air at no stage of the treatment, and the gases developed are all burned. Such a plant is employed in Augsburg.

2. Liernur has invented a process in which the excremental matter is first neutralized with about 1 per cent. of sulphuric acid, to fix the ammonia, and then boiled in a vacuum chamber. The latter corresponds closely to a three-chambered evaporator used in the preparation of sugar, in which the gases from one division aid in warming the next. The exhaust steam from the engine is used in the first chamber, after it has been superheated and thoroughly dried. The thick fluid thus produced is spread

thinly over the surface of highly heated revolving cylinders. The dry crust is scraped off by means of a second cylinder carrying a number of projections, and falls down as a fine powder. The process was tried in Dordrecht, and given up in order to install a more complete plant, it is said. In Amsterdam the process was adopted to prepare a thick fluid, which was said to be better suited for a fertilizer than the powder. Recently the process was given up on account of the great dilution of the fæcal matter, as mentioned in the preceding chapter.

3. BUHL and KELLER have adopted a process founded on discoveries by HENNEBUTTE and VAUREAL. The excrement is mixed in an agitator with from 0.4 to 1.6 galls. of a 5 per cent. solution of zinc sulphate and 0.6 to 1.2 lbs. of quicklime for every 100 galls. of the matter. The liquid is then run into large tanks where from one-fourth to one-third of its volume is precipitated, the precipitate containing all the solid and the greater part of the dissolved fæcal matter. This precipitate is compressed in a filter-press, and the cakes dried and powdered. The liquid remaining in the tank is treated with sulphuric acid to form ammonium sulphate. The process prepares, therefore, two substances—the poudrette, or dried night-soil and the ammonium sulphate,—about 42 lbs. of the former and 6½ of the latter from each 100 galls. of excrement. The final effluent is practically pure water. A plant of this kind was tried in Freiburg, but was recently given up.

Analyses of the poudrette from the three methods give the following relative proportions, in per cent., of the important constituents.

Process.	Water.	Organic matter.	Nitrogen.
1. PODEWILS	9	59–70	7.0–10.7
2. LIERNUR	15–22	50–58	6.7– 8.1
3. BUHL and KELLER	11–14	36–50	2.3– 3.6*

*This comparatively small amount is due to the fact that much of the nitrogen is changed into ammonium sulphate.

The first and second methods are preferable, since all the solid matter enters into the powder, while in the last the potash is largely dissolved in the effluent. Salts of potash are cheap and easily obtained, and the above objection is counterbalanced by the fact that one of the products, ammonium sulphate, commands a good price.

The relatively large amount of water in the LIERNUR process is due to the difficulty of completely drying any thick semi-fluid

mass. PODEWILS uses shallow pans and adds earthy matter to remedy this. In the third process there is no heating of any but perfect liquids, with which the heat is fully used.

The above difficulty also causes a difference in the amount of fuel employed, the most expensive item in poudrette manufacture. LIERNUR claims that his system will evaporate 16 lbs. of water with 1 pound of coal, a result theoretically doubtful and not yet practically shown. Theoretically the BUHL and KELLER system requires but a third of the heat necessary in the other processes. All of them must be regarded as in the experimental stage.

Other methods are employed in Paris, Manchester, and elsewhere, generally at a loss. The plants should be designed with a due regard to hygienic requirements. The 24 establishments in the neighborhood of Paris are notoriously bad, and were recently compelled to conduct their operations in metal-lined chambers with proper ventilation. They were also required to dispose of the matter within 4 days of its collection.

CHAPTER XIII

Separation of Excremental Matter.

It is sometimes considered desirable to separate excremental matter into solid and fluid portions, the latter passing away through the sewerage system and the former being removed separately. Such a plan offers the advantages, as compared with the separate removal of all such matter, of less cost and the unrestricted use of water-closets. As compared with the discharge of all the matter into the sewerage system, it results in cleaner sewers and purer rivers, since a certain quantity of more or less sticky solids is kept out of them. It is true that there is no certain line of demarcation between fluids and solids in such cases, but there are a number of processes which accomplish a partial separation.

The division takes place in the soil pipe, at the outfall of the vault, or through sand filters or perforated partitions in vaults or special pails.

1. Separation by overflow connections of cesspools and vaults with the sewers is much employed in Amsterdam, Wiesbaden, Baden, and numerous English cities in consequence of the introduction of water-closets; it is allowed in some other places. The interval between the successive removals of the solids is greatly extended by such separation, but it should be noted that the residue is in no sense an actual solid, but rather consists of a more or less semi-liquid mass, easily removed by pneumatic means. If the vault is used by 20 persons and cleaned once a year, then the outlet will discharge $365 \times 20 \times 0.25 = 1,825$ cu. ft. if it is assumed that 0.035 cu. ft. of excrement and 0.211 cu. ft. of flushing water are furnished per capita daily. The contents of the vault are insignificant compared with this volume of discharge, and it will be easily seen that nearly all the excrement must pass into the sewers.

The character of the discharge is certainly no longer that of the original excrement. After the cleaning of the vault, it will be several days before the overflow begins to discharge, and the

accumulated contents will have already begun to putrefy. The soil pipe and outfall are usually at opposite ends of the vault, and gases and certain soluble substances formed during putrefaction will check the desired precipitation during the flow from one opening to the other. Since the specific gravity of fæces is somewhat less than that of urine, it is undoubtedly true that a part of the former passes into the sewers with the latter, even when screens are used. Hence the effluent is probably between the original discharge from the closets and the ordinary contents of cess-pools in character, approaching the latter as the vault is increased in size and the intervals between successive cleanings prolonged.

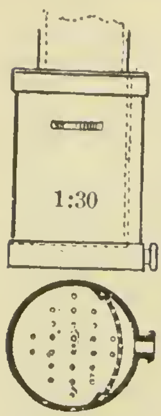


FIG. 181.

Overflow vaults are of as doubtful value in houses as those of ordinary construction, and are worse for the sewers than a complete discharge of all the excrement, since the quality of the effluent is more dangerous and the quantity is not materially decreased. The fæces, however, are usually finely divided, which is something of an advantage, but would be still greater if the effluent was passed through a gravel filter, such as has been patented by NESSLER and is shown in Fig. 182. It gives an increased opportunity for settlement and is easily cleaned, yet its use seems an over-refinement if a grating is employed and the sewers are properly constructed.

2. Separating pails, Fig. 181, connected with the sewers are used occasionally, especially in Paris and Zurich. The results of the separation depend naturally upon the size of the holes in the partition. Theoretically these should be small enough to retain all the fæces, but in this case they are soon stopped, especially in the bottom of the pail, and simple overflow results.

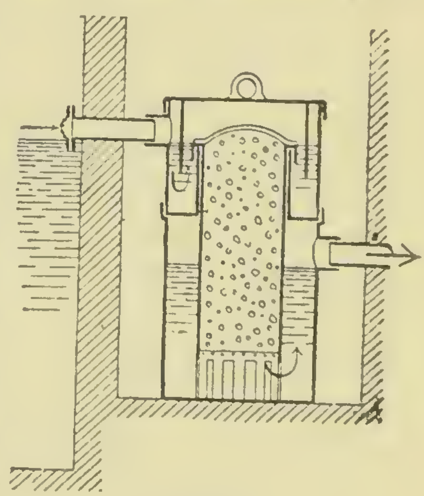


FIG. 182.

In this respect a Paris report states that the only demonstrated result of the use of these pails is that the fæces and urine enter the sewers at somewhat different times. Experience shows that about a fifth of the excrement is removed.

Thorough flushing of closets and soil pipes without increased

expense, and a protection from gases by a water-seal, are advantages not so easily obtained with ordinary as with separating pails. Moreover, the latter may be changed at longer intervals, 1 to 2 weeks, since they are not so quickly filled. Buerkli estimates the costs as equal to those of the usual cess-pool system; in Zurich the proceeds from the residue cover the expense.

The character of the effluent from separating pails is not so bad as that of the discharge from overflow vaults, since it generally passes through the partition to the sewers in a fresh state. Any quantitative gain from holding back only a fifth of the excrement is hardly to be expected. The residue will always give off some gases, necessitating good ventilation; and a frequent change of pails is desirable. On these grounds, the use of separating pails is apparently advantageous only when it is desired to remove solid matter from the effluent passing into sewers with deficient flushing facilities.

3. In Stockholm and several other Swedish cities where the use of pails is obligatory, frequent use is made of closets in which the urine is immediately separated, in the closet, from the fæces and conducted to the sewers, the solids remaining in the pails. The use of such arrangements has reduced the amount of matter separately removed in Stockholm to only 220 lbs. per capita annually. If the pails are removed at long intervals, the nuisance in the house is great, and has led to the substitution of small vessels of 12 galls. capacity for the casks holding 34 galls. that were formerly used. Moreover, the period of removal has been shortened to 2 weeks, and a regular service adopted in place of the system of removal on application, that was once in vogue.

4. Mention must be made of the high-pressure gas system of Breyer. From a vault below the house, receiving not only domestic sewage but also waste water and even refuse, the liquid matter is filtered away and discharged into the sewers, the solids being from time to time forced into a cask by a pressure of 45 to 60 lbs. per sq. in., and again filtered. The solid matter thus collected is heated to kill the bacilli and reduced to poudrette. A portable apparatus passes from house to house and furnishes the necessary pressure to compress the matter and remove it. The technical possibility and hygienic value of the system are indisputable, though it has not been actually tried. The principal objection lies in the cost both of appliances and management.

CHAPTER XIV.

DISINFECTION.

By disinfection, micro-organisms are killed and putrefaction retarded, both while the excremental matter is standing and after it has passed away. Deodorization is partial disinfection, sufficient to prevent or destroy offensive gases, but not able to kill the bacteria. Various materials have been employed for disinfecting on a large scale—earth, peat, sawdust, ashes, carbolic acid, tar, charcoal, copper and iron sulphates, quicklime, and other substances. The earthy materials work mechanically, absorbing water and excrement, fixing the gases, especially ammonia, and retaining the bacteria. Moreover, a chemical action between the oxygen they contain and the organic matter also takes place. The chemical substances change the excrement, precipitating some portions of it. Their influence on bacteria depends upon the kind of chemicals employed.

Investigations by ERISMANN on the character of the gases given off from vaults in 24 hours and the oxygen absorbed in the same time resulted as follows, the figures representing grains per gallon:

	Carbonic acid.	Ammonia.	Methane.	Oxygen.
Without disinfection	36	6.6	24	45
With iron sulphate	23	...	9	20
" garden loam	48	2.2	9	53
" powdered charcoal	55	6.4	11	52

It will be seen that the chemical action of the iron sulphate is more powerful than the mechanical action of the earthy materials. The latter absorbed more oxygen and gave off more carbonic acid, showing that oxidation rather than putrefaction was taking place. The generation of ammonia does not stop, and possibly the gas carries with it the bacteria which the earthy matter in no way destroys.

The cost of disinfection (for materials, appliances, and inspection) must be considered, as well as its actually incomplete working; and on both these grounds a thorough ventilation of a house may be more satisfactory. The process is generally restricted to buildings requiring specially complete sanitation.

1. *Disinfection with Earthy Materials.*—Since the object of such disinfectants is to substitute oxidation for putrefaction, they should be adapted to receive oxygen from the air and are preferably dry and finely divided. In respect to the absorption of gases, especially ammonia, the fineness of the particles, giving increased surface, and the composition of the substances employed, act in a manner hardly explicable. Investigations by ORTH show that a cubic yard of sand will fix, or retain, 4,100 grains of nitrogen in the form of ammonia. On adding loam and humus the absorbing capacity is increased until it reaches 5.5 lbs. with very rich clay. Hence sand is not adapted for such purposes, while humus, loam, and clay are. This variation gives rise to the diverse requirements in different places. In England, 4½ lbs. of earth per capita are generally used, while in other places as much as 11 lbs. are employed. The oxidizing power of earth remains constant so long that finally all the excremental matter will be changed to gaseous or soluble bodies. After drying, the earth may be used again and is occasionally employed 5 or 6 times. After saturation it is especially adapted for fertilizing purposes, since it contains many substances that can be directly assimilated by plants.

Ashes act much like earth, both as disinfectants and as fertilizers, and are more adapted for economical use from the necessity of their removal in any case. In many towns they are removed from the house refuse by sieves, which, at the same time, reduce the matter to the desired size. The requisite amount, twice the quantity of excrement, is rarely furnished by the house, Manchester being apparently the only place where a sufficient quantity is obtained. The sifted ashes are stowed away and used in "ash pails" as required.

The quantity of material necessary is greatly diminished by the use of some of the special preparations of peat that have recently been introduced. The peat is cut up and sifted, about 80 per cent. of the product being a coarse, fibrous mass, and the remainder a fine powder. Both forms are capable of absorbing liquids and reducing them to various gases, the powder being more efficient than the other portion. The latter, the coarse fibers, will take up 4 to 6 times its weight of water, while the powder absorbs from 6 to 12 times its weight of water and 1.5 to 2 per cent. of its weight of ammonia. Hence, if the annual excrement per capita be assumed as 970 lbs., an eighth of that

weight, 121 lbs., of powdered turf will be sufficient to absorb the matter, although not enough to take up all the ammonia. In general, the requisite amount for dwellings varies from 66 to 154 lbs. per capita annually, although sometimes only 33 lbs. is needed in schools and factories.

The bacteria in the saturated peat were found by GAFFKY and SOYKA to be of the harmless species. No injurious bacilli can exist, on account of the tendency of the material to develop acid characteristics.

The saturated peat is an almost odorless fertilizer, easily handled and employed. Its value naturally depends upon the amount of water in the excremental matter and upon the soil: for some kinds it is better adapted than compost earth, and for other kinds it is not so good. The best results are obtained with a light soil, and in any case the ingredients lacking can be easily supplied by adding small quantities of the usual commercial fertilizers. The principal advantage of the peat lies in the ease with which it can be transported. The average results of analyses of this material, after one saturation, give 80 to 88 per cent. of water, 10 to 17 per cent. of organic matter, chiefly vegetable fiber, and 0.4 to 0.8 per cent. of nitrogen. The latter is not greater than the amount present in the contents of cess-pools, but may be raised to perhaps 2 per cent. by repeated saturation.

The earthy disinfectants are applied in the closets, vaults, or receiving stations. In the first method the earth is placed in a pail or pan, either when the receptacle is cleaned or automatically by dropping the lid of the seat or moving the door of the closet. The removal is generally by the pail system, although occasionally the matter passes through soil pipes to vaults or casks. In the latter case the vaults must be emptied by hand, which is not such disagreeable labor as with the usual class of cess-pools, and takes more time.

The preparation and transportation of the disinfectant naturally increases the cost of such systems of treatment and removal of excrement, which ranges from $1.50 to $2.50 per capita annually when earth is employed. The proceeds from the sale of the saturated contents of the pails or vaults are sometimes quite large, especially when the earth is used more than once. But earth closets require a constant municipal control, which is expensive, since the householders cannot be trusted to keep the ap-

pliances in proper condition. Hence the system has only a limited use, as in Lancaster, where the urine is separately removed before disinfection and the amount of earth employed is only $\frac{3}{4}$ lb. per capita daily, and in Manchester and Rochdale, where the house ashes are sifted and the finer parts placed in the closet pails. It is better to use the preparations of peat, already mentioned, as is now largely done in Brunswick, Hannover, Oldenburg, and other places. The cost of 110 lbs. per capita annually is 40 cts.; labor and expense of removal, 55 cts.; total annual cost per capita, 95 cts. In Brunswick the saturated peat is sold at from $1 to $1.75 per ton. In Warsaw, on the contrary, the introduction of peat closets was unsatisfactory.

Disinfection in the privy vaults rather than in the separate closets appears to be commendable only where the work of control and removal is easily done, as in the country or in buildings like the Lyceum at Strassburg, where the vault is easily entered from the side instead of from above. The system is extensively employed in Christiana, where the excrement from each house runs into a shallow pit and there receives the peat and lime used for disinfecting. The thick mass contains 0.7 per cent. of nitrogen, and is highly valued as a fertilizer, bringing $4.25 a ton. Those portions that cannot be used at once are worked into compost heaps. This process avoids the use of disinfectants in the closets, and is possibly less expensive than that system. It has, however, the disadvantage of not reaching the small particles of matter that cling to the sides of the soil pipe. Both methods possess the advantage of not contaminating the soil, even with porous or otherwise defective vaults. On the other hand, it is a matter of serious consideration whether or not the earth and its contents should be allowed to dry and be again used within a house ; an objection that has led to the introduction of the following system :

In many cities the excremental matter is disinfected at receiving stations. This is done partly to preserve the fertilizing portions for future agricultural use and partly to make a mercantile product of the dry parts of the street refuse. The latter is an excellent disinfectant, and also adds to the resulting mass from 0.2 to 0.5 per cent. of its weight of nitrogen. The compost is prepared in ditches from 1 to $1\frac{1}{2}$ ft. deep, and contains from 0.3 to 0.8 per cent. of nitrogen according to the amount of water

present; so that the addition of the refuse to the excrement results in a compound containing as high a percentage of nitrogen as the latter of its two ingredients.

The fæcal compost has considerable value in some places—from 48 cts. to $1.24 per cu. yd. in Holland, 57 cts. in Glasgow, 67 cts. in Emden. In some cases the cost of removal is more than covered by the proceeds. In Emden the contractors do the work gratis; in Glasgow and Groningen a profit of 20 to 50 cts. per capita annually is made. On the other hand, in Bergen and Stockholm, there is a loss of 42 and 18 cts., respectively, per capita annually.

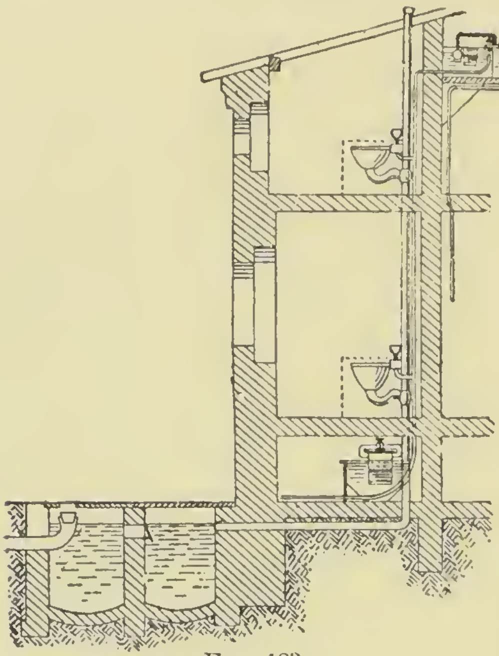


Fig. 183.

Where the compost must be carted any distance in wagons its value is considerably reduced, as in Cologne, where it is worth only 19 cts. per cu. yd. delivered at the fields. In this connection, it should be noted that in Amsterdam the excremental matter from 40,000 persons is delivered, by the pneumatic system at a central station, as already described, and is there worked into compost with the street sweepings. Sometimes the fæces are mixed with the semi-fluid matter removed from overflow vaults, in order to "freshen" it.

2. *Disinfection by Chemicals.*—Chemicals are extensively used in the "separation" system of handling excremental matter, in order that the urine passing into the sewers and the fæces remaining in the pails or vaults may be rendered harmless and odorless. The chemicals are always added in a liquid form and mixed with the excrement as thoroughly as possible. GERLOCZY recommends the use of copper sulphate and carbolic acid, as giving the best results at a small expense. A number of compound disinfectants are now in the market, but the principal ones are sold by ROEBER, in Dresden; MAX FRIEDRICH & Co., in Leipzig, and ZEITLER, in Berlin. The FRIEDRICH disinfectant contains carbolic acid, hydrate of alumina, oxide of iron, and lime. The leading systems of domestic disinfection are those of FRIEDRICH and ZEITLER.

The closets are arranged as shown in Fig. 183, and usually have a "mixer," Fig. 184, in the top story, which acts much like an ordinary flush tank, being connected at one place with the water mains and at a second place with the flushing pipe of the closets and urinals. A perforated zinc box contains the disinfectant, the flushing water is taken from the tank and a fresh supply is admitted from the mains. In the FRIEDRICH system, Fig. 184*a*, the inflowing supply passes through an injector, which forces air into the water through a perforated tube at the bottom of the tank and causes the water to circulate through and around the box of disinfecting material. In the ZEITLER system, Fig. 184*b*, the water has to pass through two conical

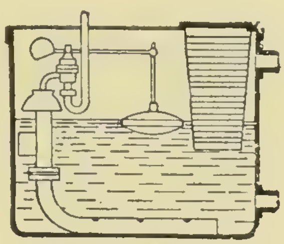


FIG. 184*a*.

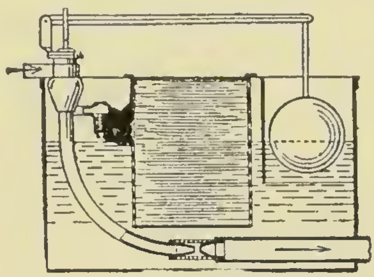


FIG. 184*b*.

orifices, and in this way a series of little waves is caused, which effectually send the water through the box. The closets are thus flushed with disinfecting water, which also passes through the soil pipe into the vault, and there precipitates the solids by the sulphate of alumina and lime it contains. The first vault is usually connected by an overflow opening with another, called the settling tank, where the remaining suspended matter is removed and a fairly pure effluent enters the sewers. The sewer connection can generally be closed by a valve, in order that the contents of the vaults may stand a sufficient time to separate into solid and liquid portions.

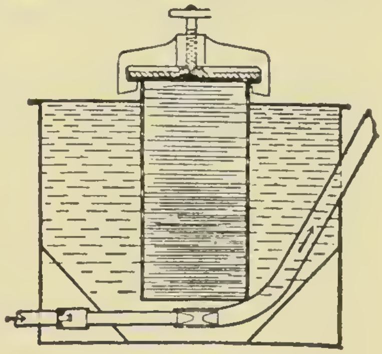


FIG. 184*c*.

Various modifications of this general process have been proposed from time to time. The following are the most important :

a. The mixer is sometimes placed below the closets, Fig. 184*c*, in order to save piping and diminish the probability of freezing. The whole apparatus is then tightly closed, and the

pipe to the closets is somewhat larger than that to the mains, in order that the flushing water may contain a portion of the contents of the mixer. A check valve prevents the passage of water in the wrong direction.

b. A mixer is sometimes employed for each closet, in order that the existing piping need be altered as little as possible. In such cases a small apparatus is placed below each seat.

c. A mixer is occasionally placed near the vault, into which the disinfecting solution is discharged once or twice weekly in houses, and more often in large buildings. Special attendance is necessary in this case, and the closets and soil pipe no longer receive any benefit from the process, which has led to its official prohibition in Berlin. It has the advantage of requiring no alteration in existing piping, and was recently recommended by FRIEDRICH. It is now the standard system in Karlsruhe.

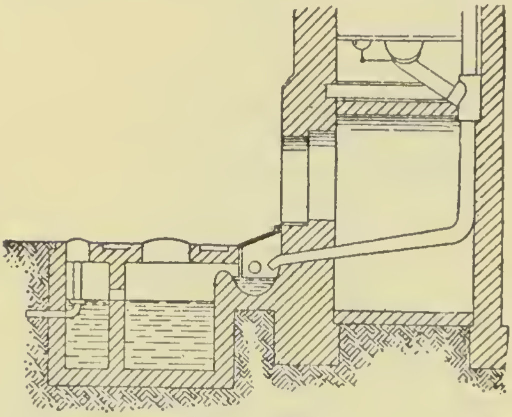


FIG. 185.

d. Where there are no suitable water pipes, the excrement itself is used to dissolve the disinfectant, which is contained in a small tank, as shown in Fig. 185. The results of such an arrangement are uncertain.

The thoroughness with which the process is conducted is tested by chemical analyses of the contents of the second vault. The liquid must have an alkaline reaction when the disinfectants are properly added, usually once a week. The standard effluent contains, besides carbolic acid, 35 grains of quicklime per gallon, which have been found sufficient to prevent putrefaction. Since it also contains nearly all the nitrogen of the excrement, the deposits in the vaults have little agricultural value, and the interception makes no material change in the hygienic character of the sewers and rivers, serving chiefly to prevent deposits in the sewerage system. In this respect, the chemical separation is more efficient than the mechanical.

This system of simultaneous disinfection and separation is permitted in Leipzig, Dresden, Chemnitz, Hannover, and Karlsruhe, and is extensively used in the cities of Saxony, where the separation of fæces is regarded as of fundamental importance.

In the still unsewered districts of Berlin, where there is a water service, the system is employed, and the purified effluent allowed to flow off in the street gutters.

The cost of disinfection is stated by FRIEDRICH to be 22½ cts. per capita annually for small dwellings and less for larger houses. The removal of the sludge in the tanks may be estimated at 10 to 18 cts. Since the sludge has no commercial value, the cost of the system averages from 25 to 38 cts., sometimes rising to 50 cts. per capita annually. In addition to this sum is the expense of public supervision, without which the process might not be properly conducted. The frequent presence of these officials in a house is certainly unwelcome, and an official report of a Prussian committee declares such supervision to be "impossible and hateful." On this account the plan is not suited for large cities, and will probably be restricted to public buildings and the better class of private houses.

The cost of the FRIEDRICH system, as well as alleged choking of the pipes, have led to its rejection in favor of simply manual addition of the disinfectant, either in the vault, as in the SUEVERN-ROEBER system, or else in the closet. The latter plan is plainly the better, since the closets and soil pipes are then disinfected. But official inspection is then absolutely essential in order to insure that the additions of disinfectant are made at the proper interval, and the system is best adapted for places where it is sure to be properly conducted, as in hospitals and railway stations.

Waste water is also disinfected in some places, either by flushing the kitchen and other connections with disinfecting water from the mixer or by conducting the waste to the vault, which must then contain a somewhat increased amount of the disinfectant.

PETRI has proposed to dispose of the sludge in the vaults by mixing it with peat and pressing the mass into bricks, which will burn cleanly and without odor.

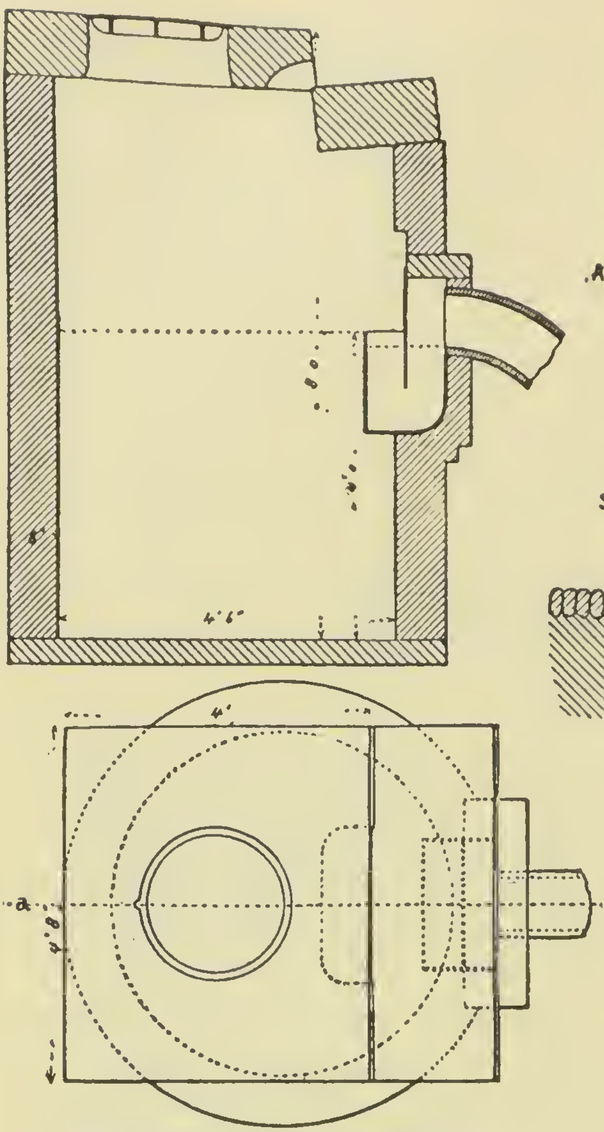


FIG. 187.—PROVIDENCE CATCH-BASIN.

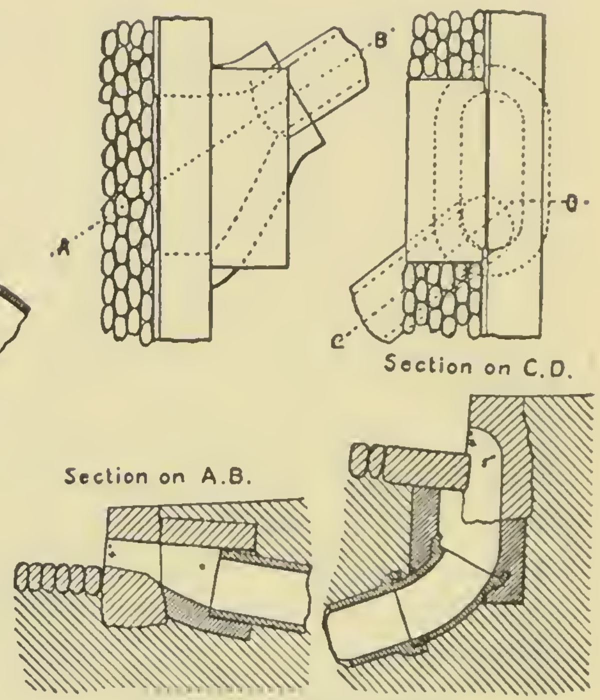


FIG. 188.—EXTRA INLETS.

Weights, 167 and 177 lbs.

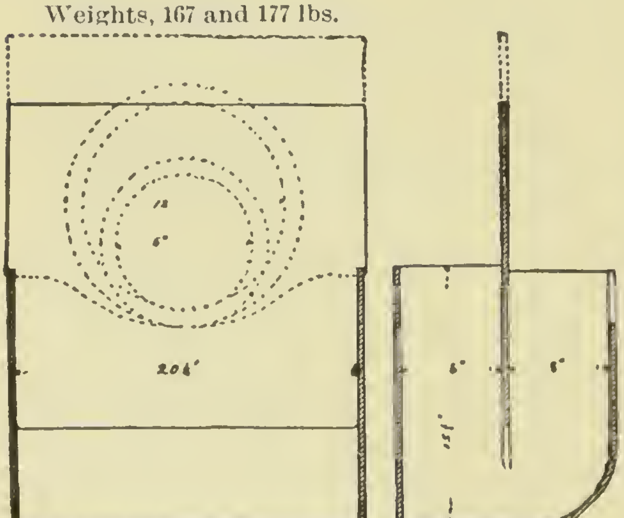


FIG. 189.—MODIFIED CROES TRAP.

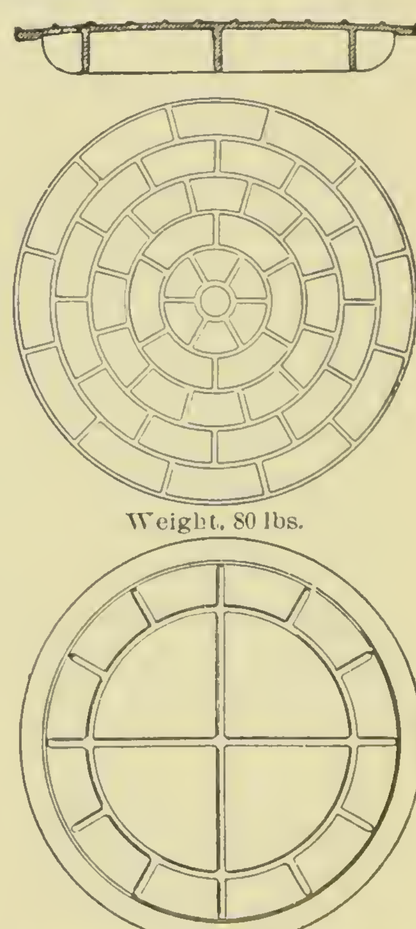


FIG. 190.—CATCH-BASIN COVER.

NOTES ON AMERICAN PRACTICE IN STREET MAINTENANCE AND SEWERAGE.

The following matter relating to sewers, street maintenance, and the disposal of refuse is chiefly taken from a series of articles on municipal engineering, published in ENGINEERING NEWS in 1886. These articles were prepared by engineers connected usually with the departments described, and give the actual practice at that date in the several localities mentioned. The illustrations were prepared from standard drawings furnished by the departments.

CATCH-BASINS AND TRAPS.

Fig. 186 illustrates the Boston standard design for a catch-basin. These basins are usually located about 250 ft. apart, with the

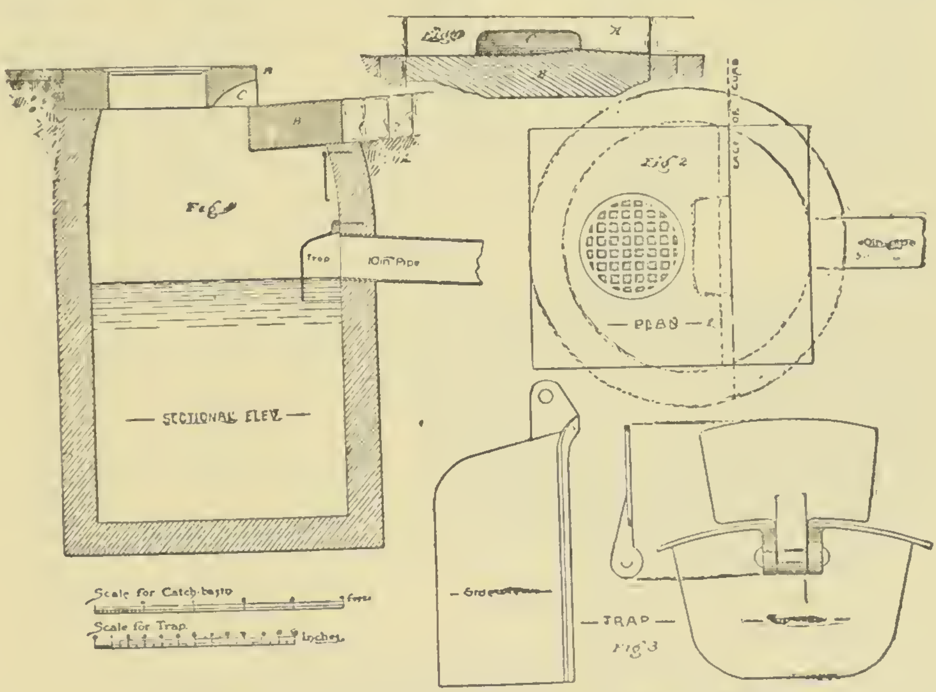


FIG. 186.—STANDARD CATCH-BASINS, BOSTON, MASS.

manhole in the sidewalk, as shown. When this basin is on a grade in the street the entrance-stone is so shaped as to divert the water into the curb opening, as indicated. The trap here illustrated is open to the objection that, if the water in the basin has to be passed out of the 10-in. pipe, or if this pipe is in any

way obstructed, the cement seal about the hinged trap must be broken and then renewed. The usual practice, however, in emptying this basin is to dam the gutter entrance and then hoist the water out of the manhole in buckets.

Figs. 187 and 188 illustrate the Providence standard catch-basin with a modified form of the Croes trap. The bottom of this basin is formed of North River flagstone, and the brick walls are 8 ins. thick and lined on the inside with cement mortar up to the water line. Fig. 189 shows plans and sections of different

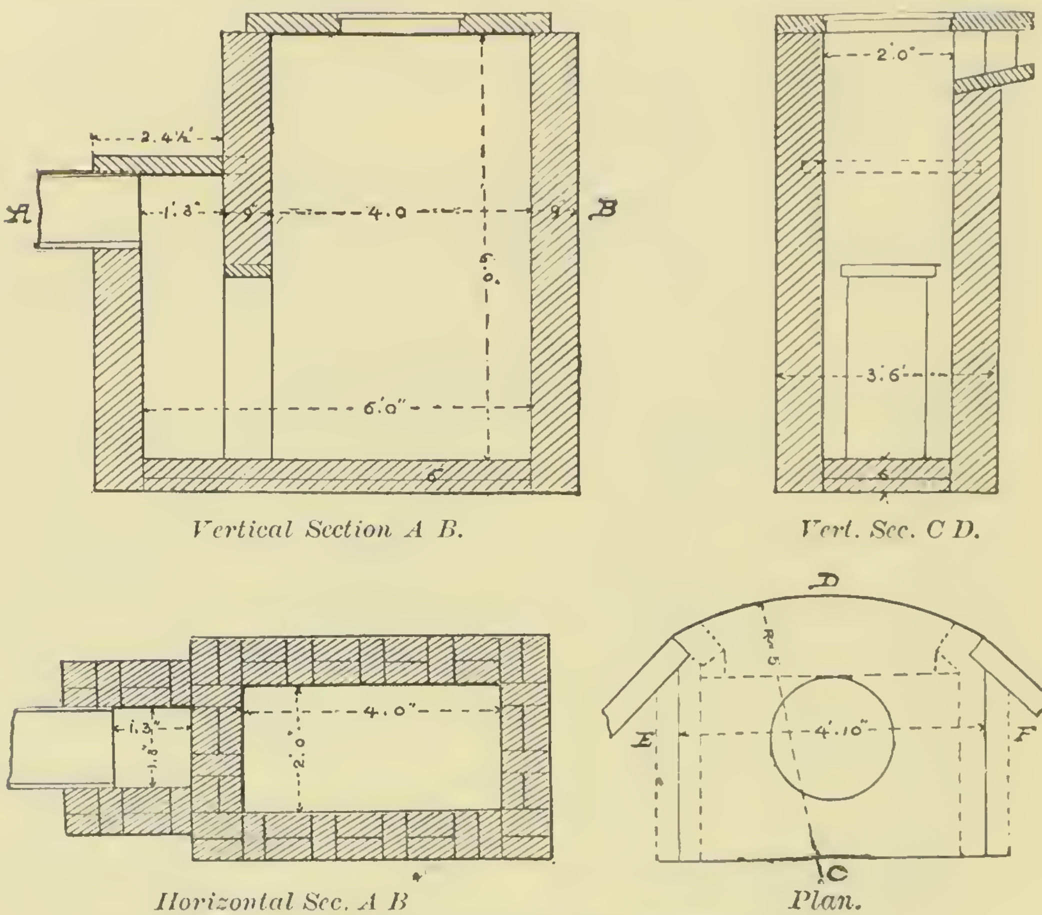


Fig. 191.—Catch Basin, Washington, D. C.

types of "extra inlets" to catch-basins, by the use of which the number of such basins is reduced, the water is more easily disposed of, and the amount of water flowing over the crossings is reduced. The style of catch-basin cover is shown in Fig. 190.

The standard catch-basin used in the city of Washington, D. C., is shown in Fig. 191. These basins are built of brickwork, made perfectly water-tight by an interior coating of neat hydraulic

cement ½ in. in thickness. The cover of the basin is usually 4-in. flagstone; the manhole opening is 2 ft. in diameter, and is closed with a cast-iron cover; the throat-stone and side-stones are of granite. The usual dimensions of this basin are as follows: Gutter opening, 3 ft. 5 ins. long by 8 ins. high; the interior of the receiving basin is 2 ft. by 4 ft. and 6 ft. deep; the "stench-box" is 1 ft. 3 ins. square, and the bottom of the discharge pipe is located 6 ins. above the top of the opening connecting the receiving chamber and the stench-box.

Fig. 192 shows an alley and gutter basin of the same general construction as the one described above, but smaller and covered with an iron grating. This drop is used in alleys, street gutters, and at public hydrants to carry off waste water.

The Philadelphia standard catch-basin is illustrated by Fig. 193. While the general design is somewhat similar to the Washington catch-basin, just described, the detail is more elaborate, and the parts subject to wear in cleaning are faced with flagstone. The arched cover to the stench-box is also less liable to permit the escape of noxious gases than the single cemented stone used in the former case. Fig. 194 shows a cast iron catch-basin used to some extent in Philadelphia. The trap here is an initial part of the casting.

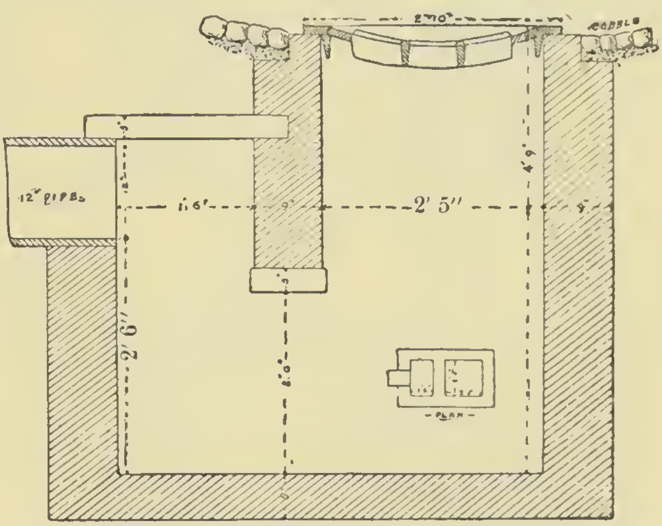


FIG. 192.—ALLEY AND GUTTER DROP.

A form of catch-basin used in the city of Louisville, Ky., by R. T. SCOWDEN, City Engineer, is shown in Fig. 193*a*. This basin is constructed of brick laid in hydraulic cement. According to the specifications provided, the bottom of the excavated pit is first covered with a 2-in. layer of concrete, and on this is laid a course of brick flatwise, thoroughly imbedded in cement mortar. Over the brick is a 1½-in. course of cement mortar, and on this is laid another of brick flatwise. On this upper course of

brick is laid a flooring of 2-in. oak boards, to prevent disturbance of the brick, or wear in removing the contents of the basin.

The side walls are carried on the brick and concrete only; though one or two brick courses are allowed to project inside over

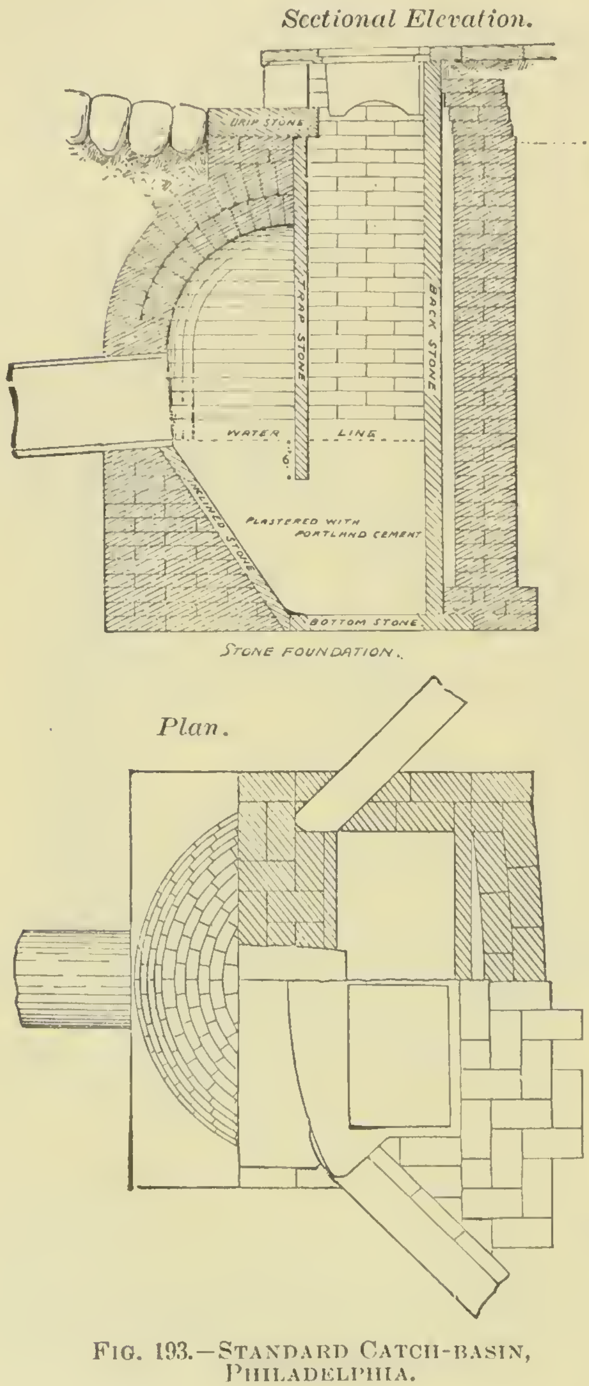


FIG. 193.—STANDARD CATCH-BASIN, PHILADELPHIA.

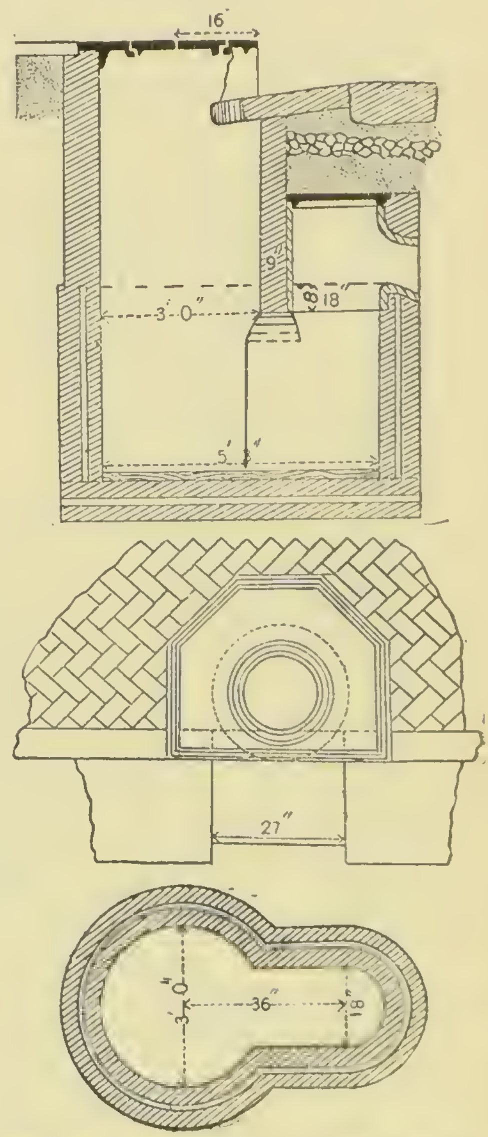


FIG 193a.—LOUISVILLE CATCH-BASINS.

the boards to keep them in position. In carrying up the walls a space $1\frac{1}{2}$ ins. wide, is left between the inner and outer rows of

brick, which space is thoroughly fitted with cement mortar as the bricks are laid. The space between the outside of the brickwork and the sides of the pit, about 2 ins., is also well filled with

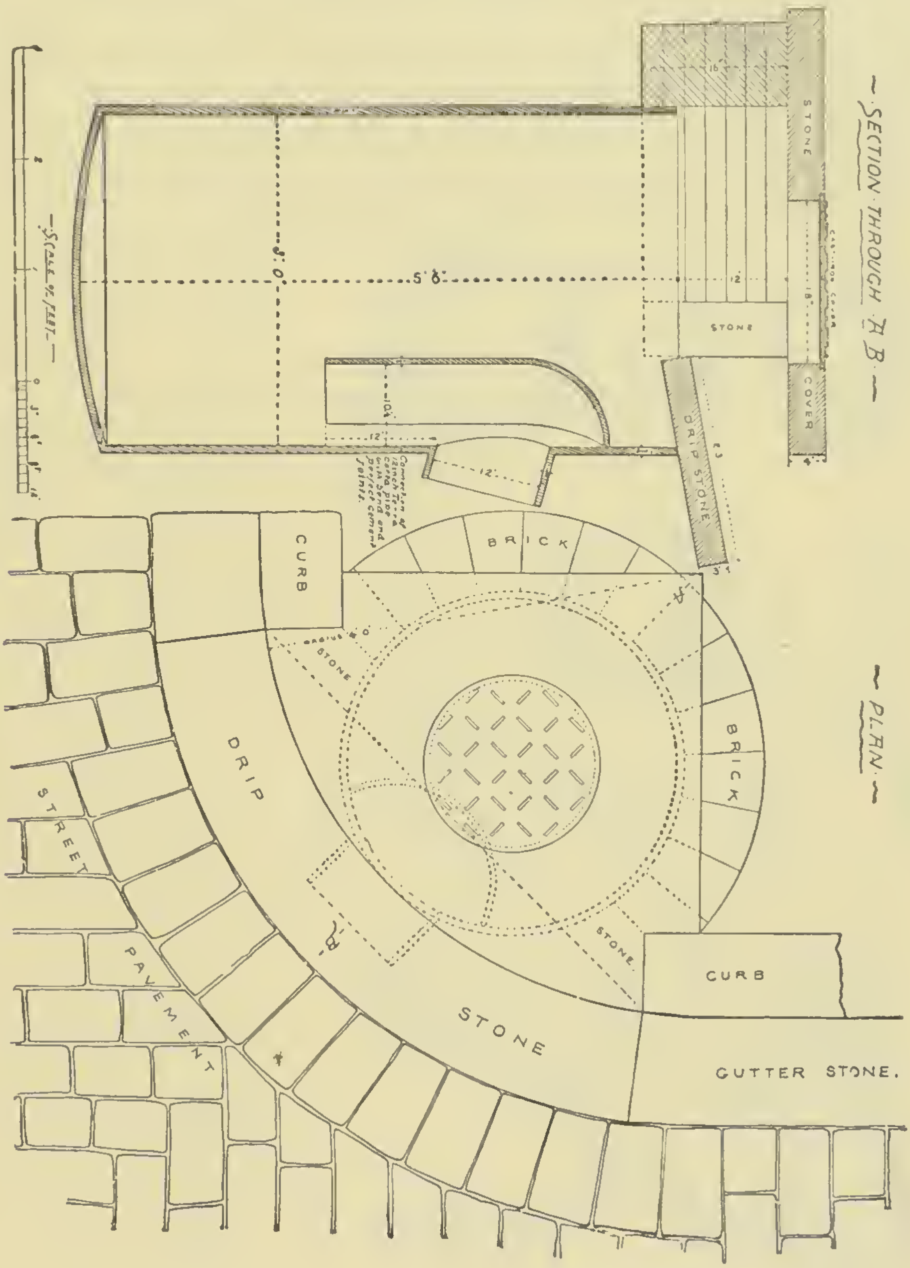


FIG. 194.—CAST-IRON CATCH-BASINS.

cement mortar. The trap shown is made of stoneware, and is provided with a tight iron cover.

Sewer Sections.

The following sketches illustrate various American types of sections adopted for sewer construction. Fig. 195 is reduced from an illustration in "Main Drainage Works of the City of Boston, Mass.," by Eliot C. Clarke, C. E., engineer in charge. Taking the figures found upon this plate, Figs. 1 and 2 show the 10 ft. 6 in. main sewer, with rubble side walls; Fig. 3 is the bond used in the spandril; Figs. 5 and 6 are the manholes and their connections, with the wrought-iron step shown at Fig. 7. These manholes are usually located 400 ft. apart. Fig. 9 shows the sewer in conglomerate rock and coarse sand.

Fig. 10 represents a portion of this sewer where it is carried over a bed of marsh mud from 20 to 86 ft. deep. In this case the intended street was first filled in and the sewer then built with a wooden shell, formed of 4-in. spruce plank 10 ins. wide. Every fourth plank was wedge-shaped on the radial line, and the whole structure was securely spiked and treenailed together. It was finally lined with 4 ins. of brickwork, and the average cost complete of a sewer 10 ft. 6 ins. in inside diameter was $56 per lineal foot. In the course of about two years this section settled in a long curve 18 ins. below the original grade line, but without any apparent damage.

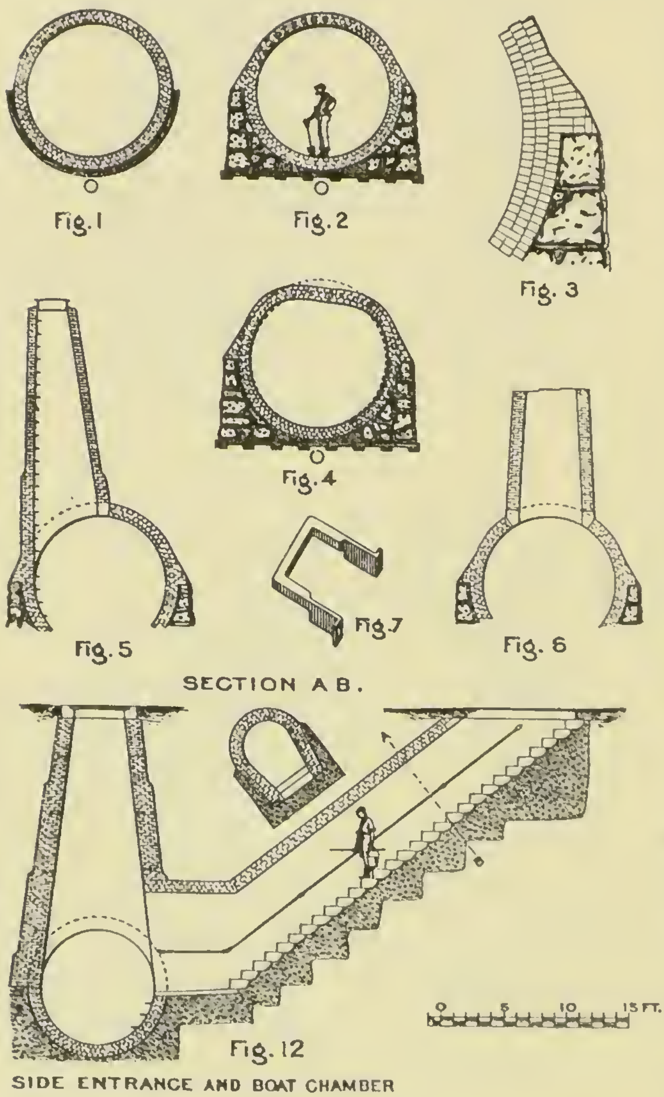


Fig. 195.

Fig. 11 in this plate shows a portion of this sewer passing within 35 ft. of a large gasholder. Sheet-piling was used here as a precaution, and the trench was back-filled with concrete to the level of the crown of the arch. Figs. 12 and 16 show side entrances and a boat chamber, the opening to the street being rectangular, 11 ft. by 4 ft., large enough to permit a boat to be passed down to the sewer for inspection purposes. Fig. 13 illustrates a pile foundation; and Figs. 14 and 15. tunnel sections. The total cost, in 1878, of 3.2 miles of this main sewer, 10 ft. 6 in. diameter, was $606.031, or about $36 per lineal foot.

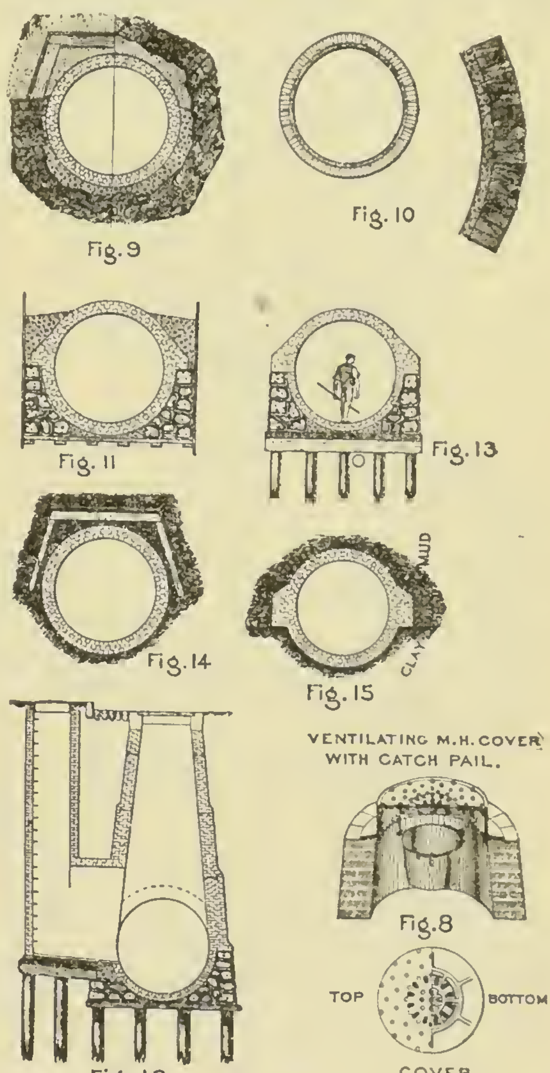


FIG. 195a.

The standard section for oval sewers in the city of Providence, R. I., is shown in Fig. 196, together with a table of elements used by the city engineering department in figuring upon sewers of this type. These elements are all given in parts of the smaller or horizontal inside diameter, *D*, and are self-explanatory.

The standard type for Washington, D. C., is given in Fig. 197. The present practice in this city is to make all sewers above a 24-in. pipe in size egg-shaped up to a maximum size of 10 × 15 ft. No pipe sewers less than 8 ins. in diameter are put down, and these are laid in concrete, as shown at the base of the cut. This concrete is 6 ins. thick on the sides and bottom, and the joints are covered by a band laid in hydraulic cement. T-branches for 6-in. house connections are put in when the sewer is being constructed, and a record kept of the distance of these connections from the nearest manhole.

In egg-shaped brick sewers varying in size from 2 × 3 ft. to and including 4 × 6 ft. the invert is made of the half of a terra-cotta pipe laid in Portland cement. For the invert of all sewers larger than this a paving of trap or granite blocks is set in Portland cement. In the brick sewers terra-cotta junction blocks are set in for house connections just above the springing line of the arch. The minimum radius for turning angles is 50 ft. in all cases.

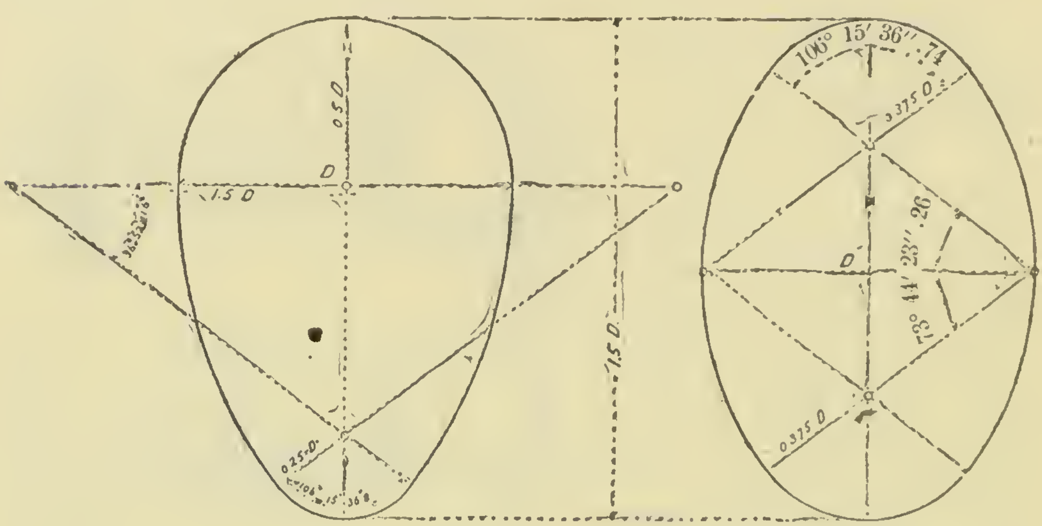


TABLE OF ELEMENTS

Name.	Egg Shape.	Four-Cen. Ell.
Area	1.1485321 D^2	1.1728072 D^2
Periphery	3.9649467 D	3.9649519 D
Mean hydraulic radius, when full	0.289671 D	0.295794 D
Approx. value of D in terms of the dia. σ of a circular sewer of equal capacity of discharge	0.8388 σ	0.8272 σ

FIG. 196.—SECTIONS OF OVAL SEWERS, PROVIDENCE, R. I.

In the upper corner of Fig. 197 a drop for dry-weather flow is shown, to be used in cases where it is undesirable to discharge into a stream, unless the sewage flow is very much diluted by the rainfall. As will be seen, the ordinary flow runs over the stone sill into a square receiving basin below, and is carried in a pipe sewer to a proper sewage outlet. In the case of a storm, the increased velocity due to the greater volume causes this diluted flow to leap the drop opening and to pass to the storm outlet.

In Philadelphia, Pa., both circular and oval sewers are used, as is shown in Fig. 198, both being maximum sizes of their class.

No special explanation of these sketches is necessary. The house connections are 6 ins. in diameter and are located 15 ft. apart. They are inserted about 45° above the springing line and at an angle of 45° with the sewage current. Fig. 198*a* shows the pipe sewers and their concrete beds, as constructed in this city.

SEWER DETAILS.

Manhole Covers.—Figs. 199 and 200 illustrate the ventilated manhole cover and its catch-bucket used in the improved sewer-

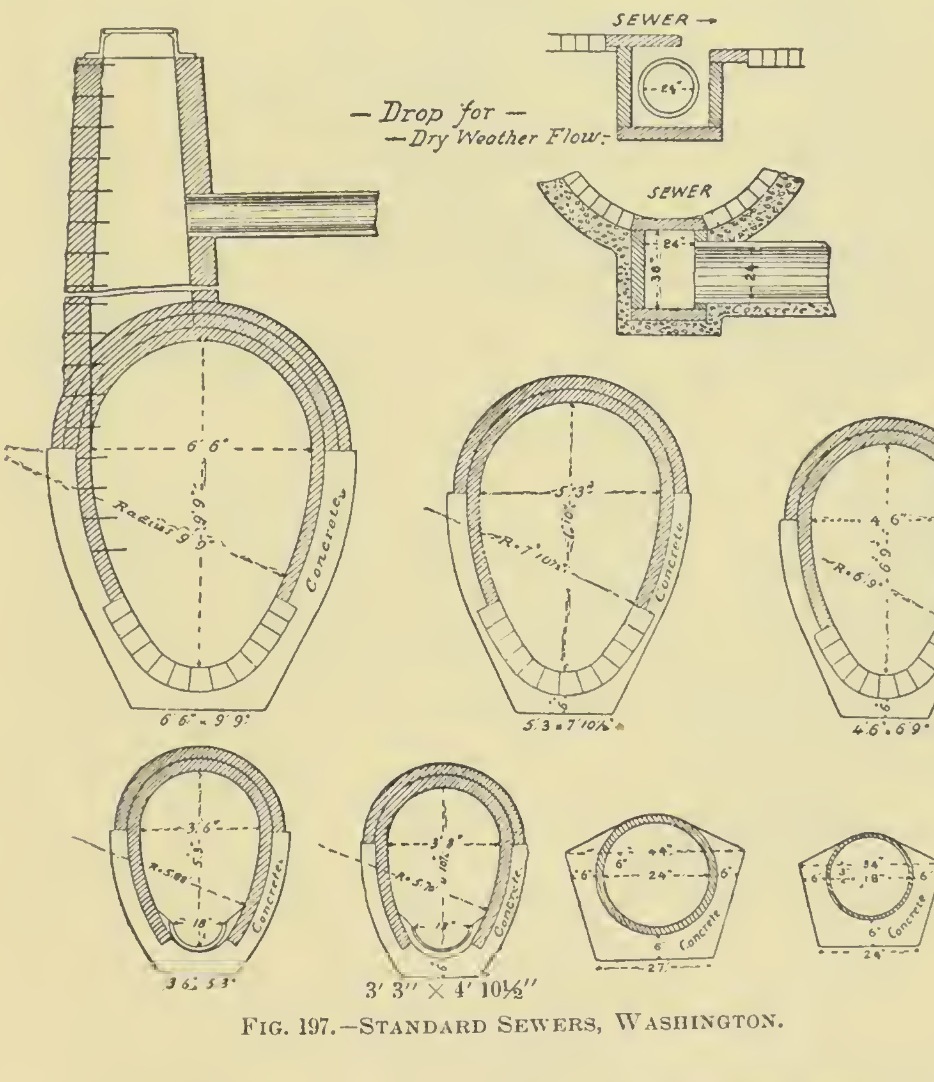
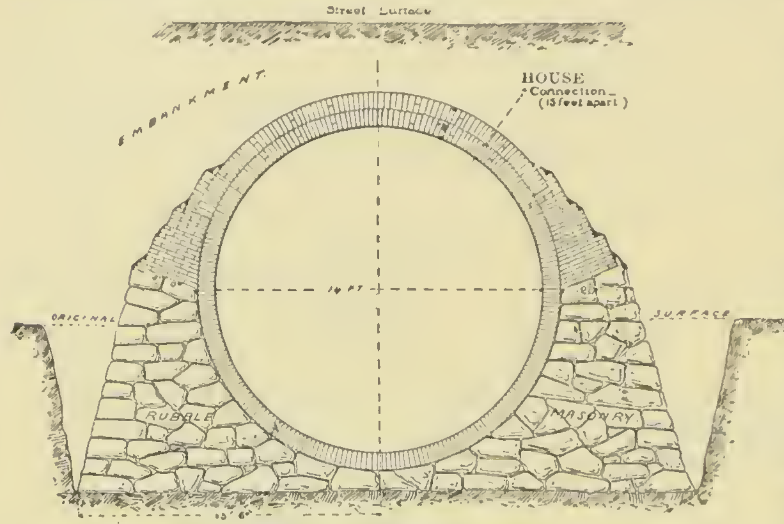


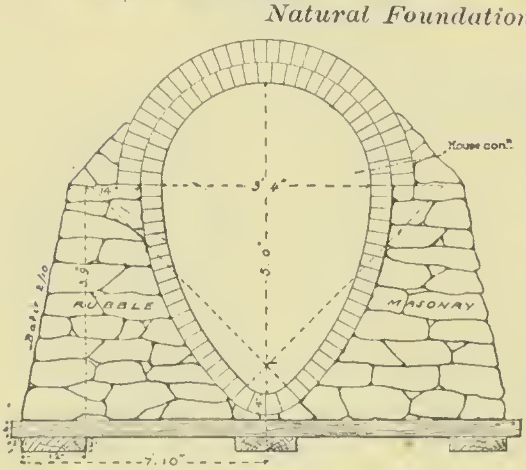
FIG. 197.—STANDARD SEWERS, WASHINGTON.

age of Boston, Mass. This studded cover has been carefully designed and well tested ; and the bucket suspended under it, as shown in Fig. 8 of Fig. 195*a*, is intended to catch any dirt from the roadway, or miscellaneous rubbish that might pass through the

openings in the cover. The bucket is made of galvanized iron, well coated with tar, and is lifted out and emptied as occasion requires. Fig. 201, page 245, shows a similar manhole cover and bucket in use in Philadelphia, Pa. The standard frame and cover as used in Providence, R. I., is given in Fig. 202, page 246.



Natural Foundation.



Type of Maximum Section on Artificial Foundation.

FIG. 198.—STANDARD SEWERS, PHILADELPHIA.

Sewer Connections.—The standard connections for sewers as printed on the back of drain permits issued by the city of Boston are shown in Fig. 203. The connections for pipe and brick sewers are of the usual type; but the third illustration is made necessary by the old wooden sewers still in existence in that city. Beveled connection pipes of 6, 8, and 12 in. diameter are given in Fig. 204, as used in Providence, R. I.

Manholes to Sewers.—In addition to the form of manhole used in the Boston improved sewerage work (Fig. 195), we have in Figs. 205 and 206 the standard type used in Providence,

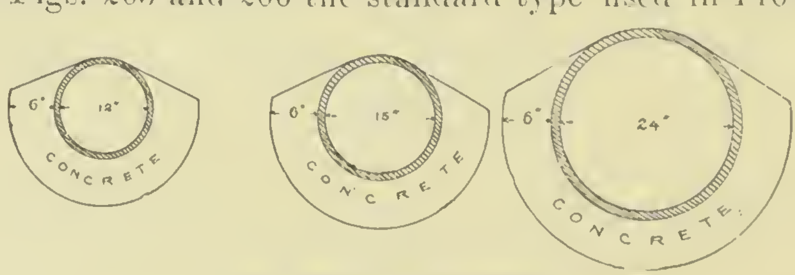


FIG. 198*a*.—PIPE SEWERS.

R. I., for deep and pipe sewers. The standpipe shown with Fig.

205 is located with its top 11 ft. below the general surface of the street; it is put in when the sewer is built and equalizes the

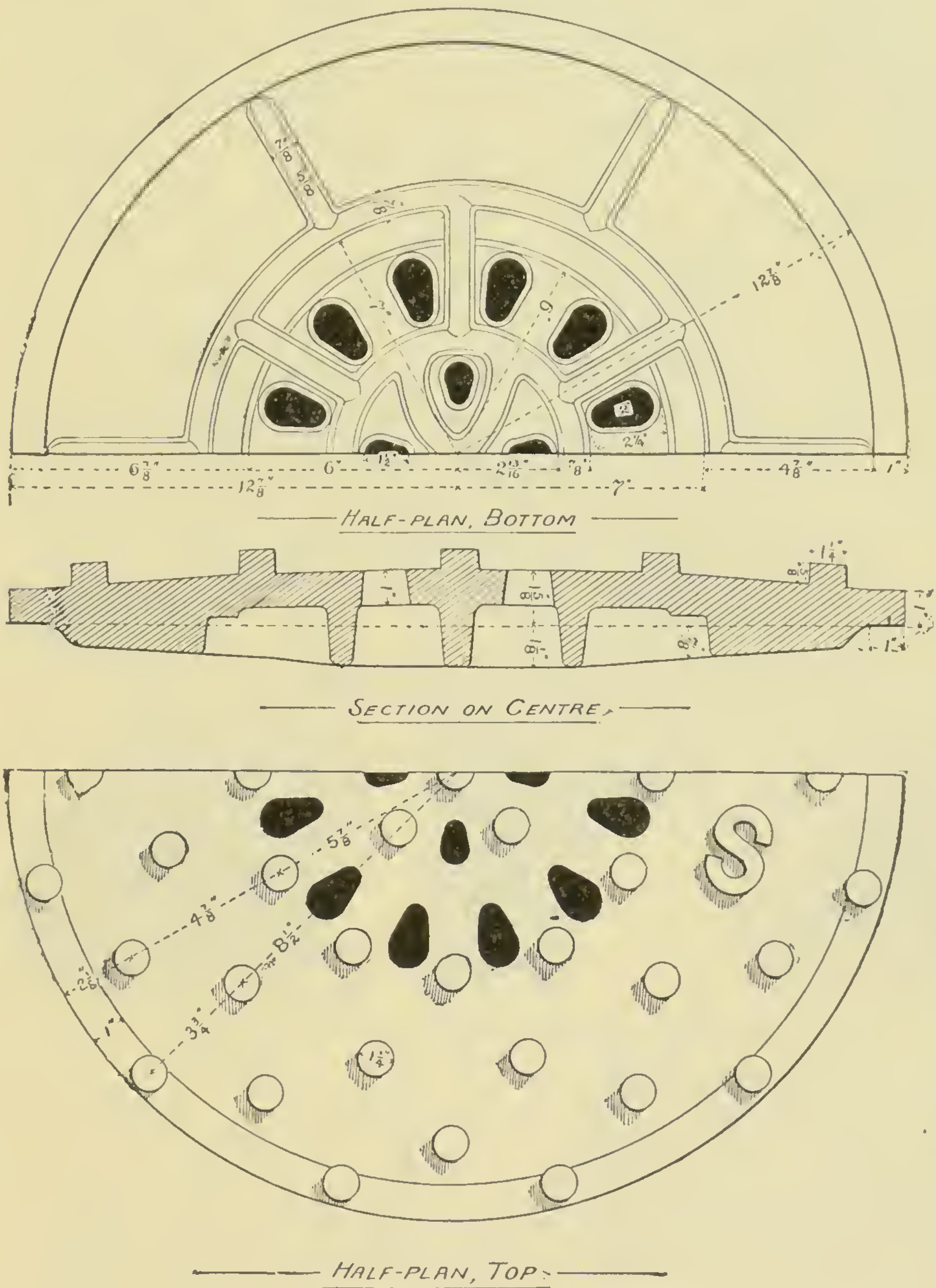


FIG. 199.—VENTILATED MANHOLE COVER.

depth of cutting for future house connections, regardless of the depth of the sewer proper. The method of building manholes on

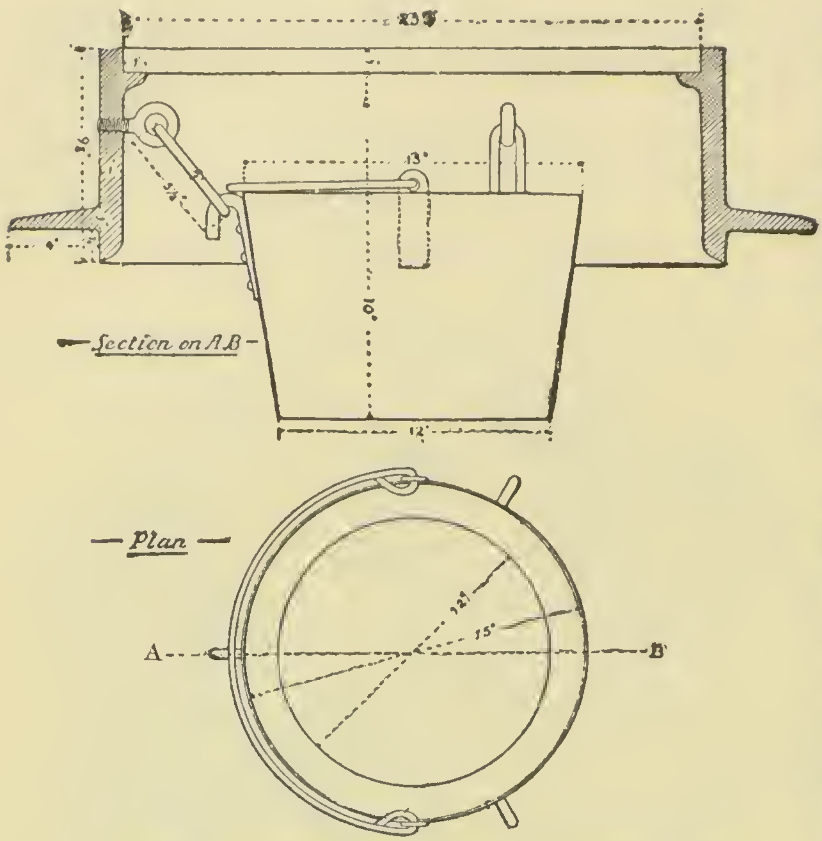


FIG. 200.—CATCH-BUCKET UNDER VENTILATED COVER.

large sewers in Philadelphia is shown in Fig. 207. Wrought and cast iron steps for manholes are illustrated in Figs. 206 and 207*a*.

Invert Blocks.—Where the work of laying sewers has to be conducted in wet ground, invert blocks are employed for the bottom portion. Those used in Providence, R. I. (Fig 208), are made of good clay, well burned and salt-glazed, similar in these respects to sewer pipe. These blocks are hollow and are made in two sizes, to conform to 8-in. and

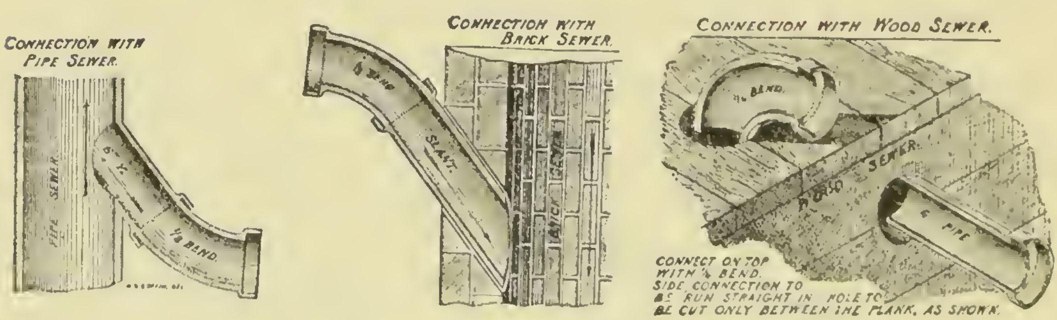


FIG. 203.—SEWER CONNECTIONS, BOSTON, MASS.

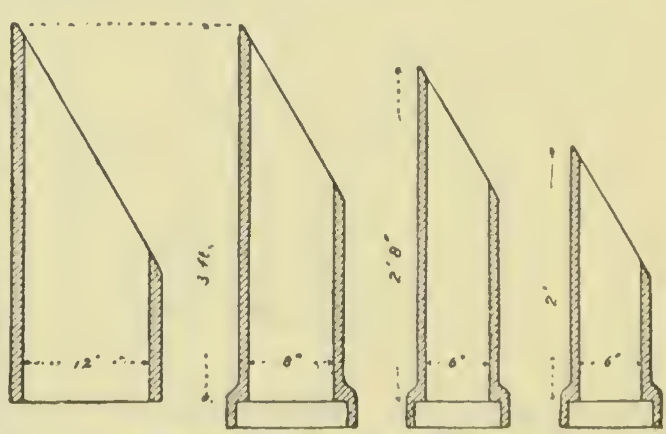


FIG. 204.—BEVELED CONNECTIONS.

4-in. brickwork, and each block is 2 ft. long. In Philadelphia, blocks of concrete and a combination of concrete and brick are used for the same purpose. (See Figs. 209, 210.)

Flushing Small Sewers.— A device introduced in Boston some years ago and successfully used for flushing small sewers is shown in Fig. 211. The cut illustrates the general arrangement

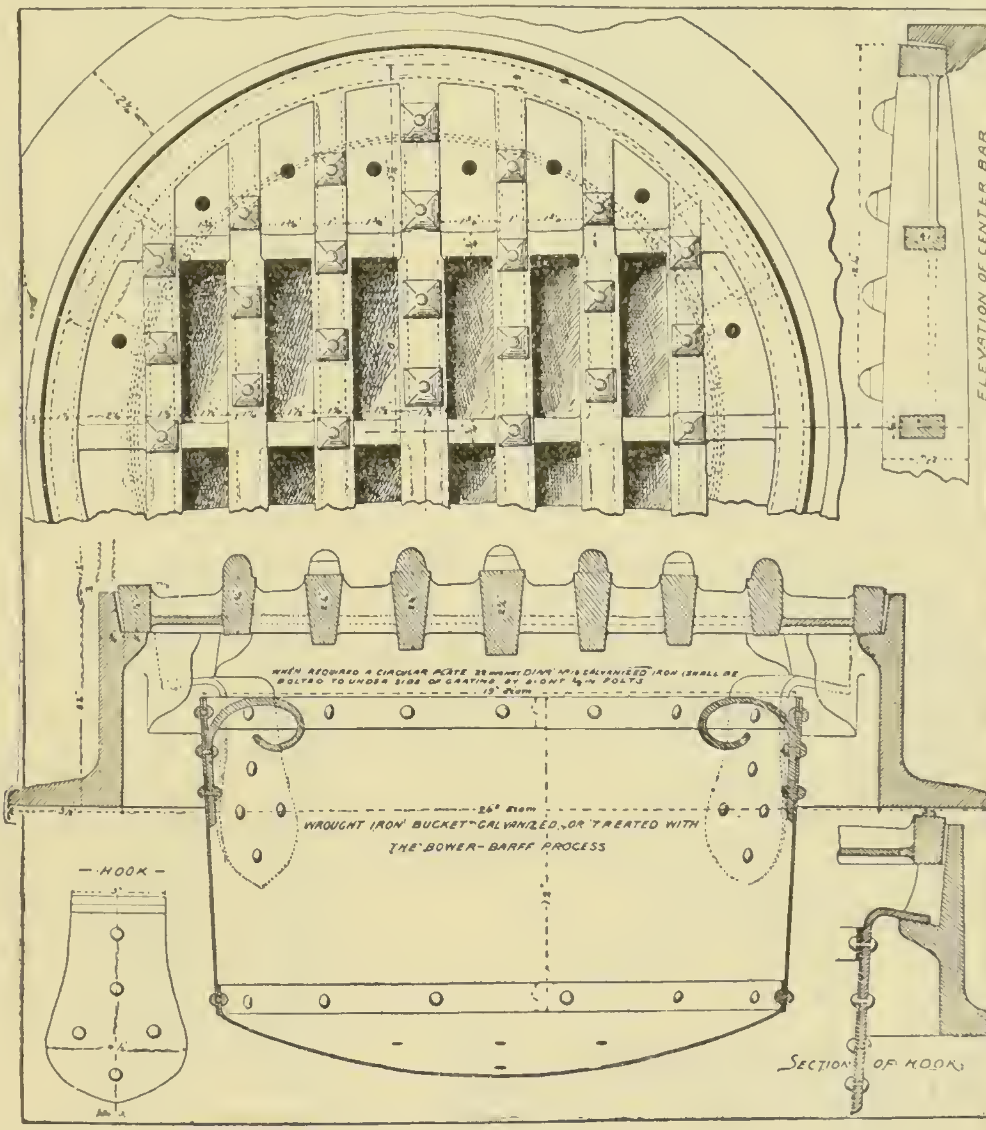


FIG. 201.—MANHOLE COVER AND CATCH-BUCKET.

adopted for a 3-ft. circular sewer, though it is understood that the same method was applied with success to an oval sewer 5 ft. high by 2 ft. 8 ins. wide.

For convenience in passing it down the sewer manholes, the "kite" or scraper is made in two parts, as shown. The bottom brace and roller keeps the rope from being cut by the brickwork

and fairly in the axis of the tunnel, and a couple of turns of the rope around the top frame enables the attendant to control the forward movement of the scraper.

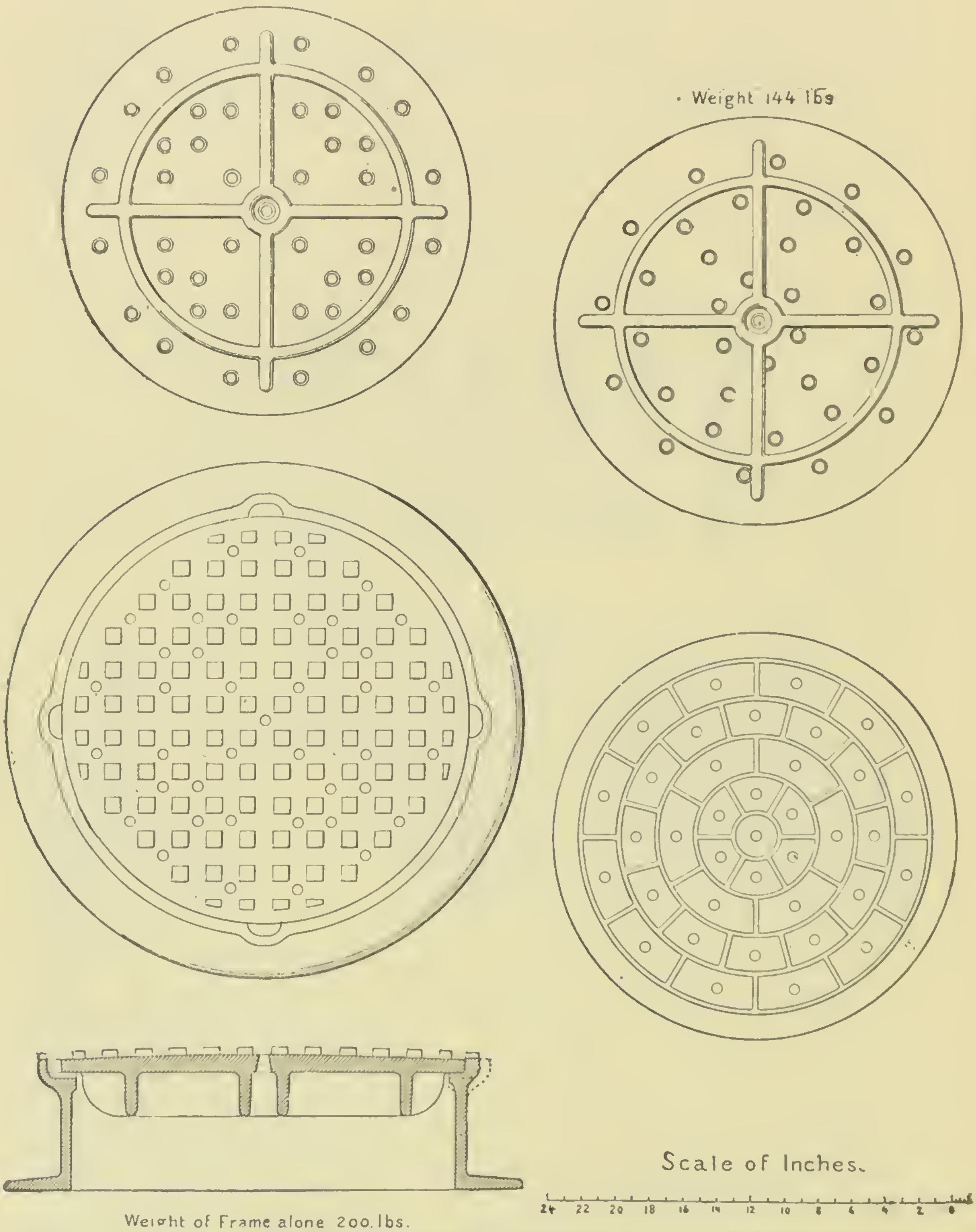


FIG. 202.—KNOBBED MANHOLE COVER. FIG. 202*a*.—PLAIN MANHOLE COVER.

In practice, the trailing wheel was found to be a necessary adjunct to counteract the backward tip of the frame resulting

from the weight of a long rope. In using this scraper it is put together as shown, and is then held stationary just below the manhole until a sufficient volume of water has accumulated behind it. The scraper being somewhat smaller than the sewer sections, the water escapes through the annular space in the form of a thin sheet or jet, and with a velocity due to the head secured, some-

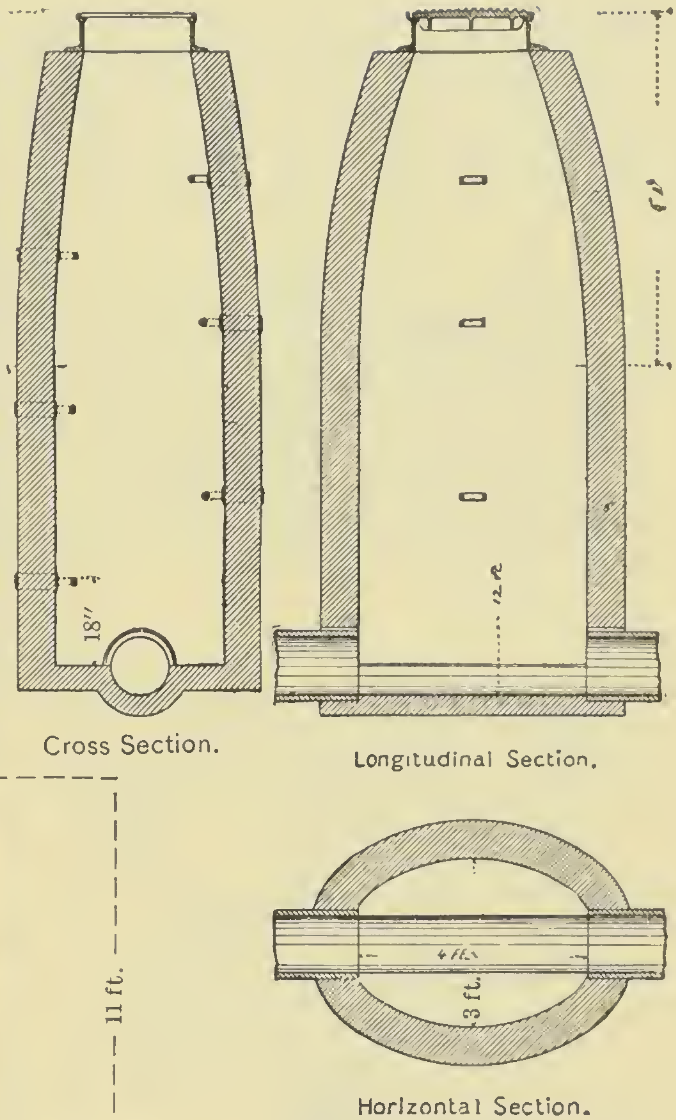


FIG. 206.—MANHOLES ON PIPE SEWERS, PROVIDENCE, R. I.

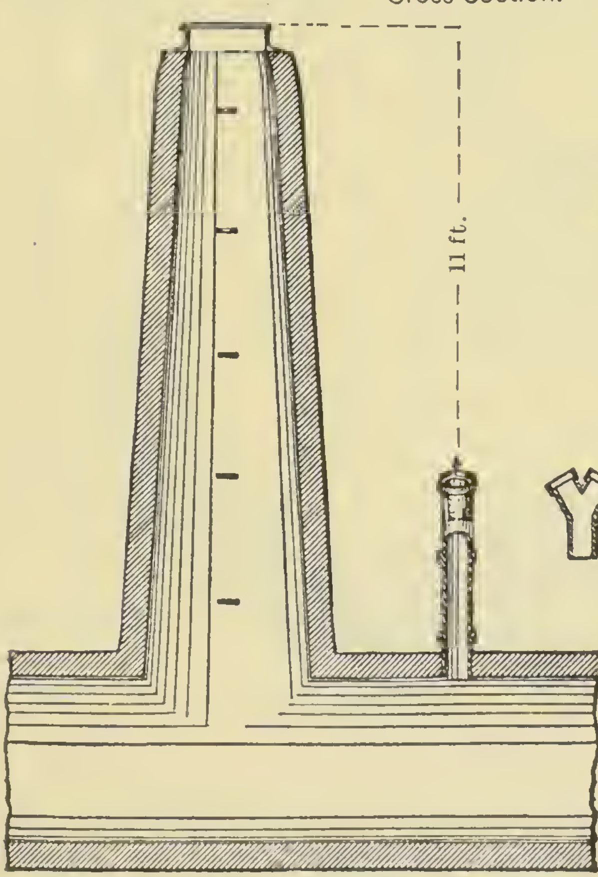


FIG. 205.—MANHOLE ON DEEP SEWER.

times equaling 16 ft. per second. As the rope is slowly paid out the scraper advances and pushes before it a bed of sand and gravel, sometimes 8 ins. deep and 100 ft. long in the Boston practice. When the débris becomes too heavy the scraper is

stopped at a manhole, the water is allowed to resume its usual low level, and the rubbish is hoisted out.

Sewer Cleaning.—F. Floyd Weld, City Engineer of Waterbury, Conn., in 1885, describes the following appliance for cleaning out small sewers. In the city named there are about

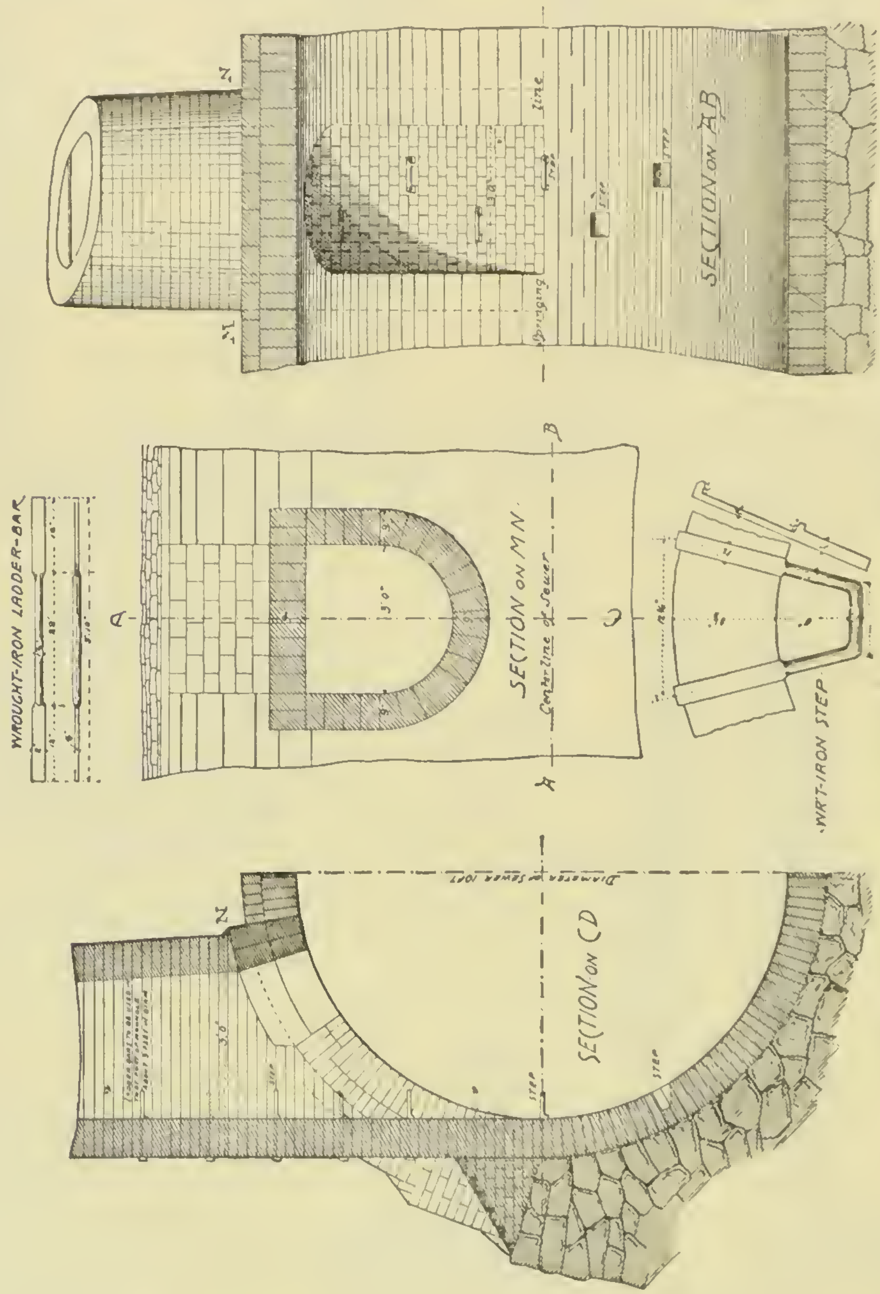


Fig. 207.—Large Sewer Manhole, Philadelphia, Pa.

10,000 lin. ft. of sewers, 1 ft. 6 in. by 2 ft. 3 in. These sewers carry storm water from catch-basins, and those having a light grade were found to retain sand and mud carried in from unpaved streets.

As men cannot enter these sewers, the engineering department devised the apparatus shown in Fig. 211a. This was a three-leg derrick, a scraping bucket, and a pulley set in a frame, as shown in the cuts. The derrick stood about 8 ft. high, and attached to two of the legs was a winding-drum operated by two ordinary carriage wheels.

The bucket, or scraper, was made of galvanized iron, strengthened by iron bands around the two ends. It was 8 ins. in diameter, about 2 ft. long, and provided with a flaring collar or mouth. To the inside of the mouth an iron bail was riveted. The pulley shown was 6 ins. in diameter, and a band of iron $2 \times \frac{1}{2}$ ins. connected the two ends of the $1\frac{1}{4}$-in. iron shaft. This curve conformed to the crown of the sewer. A turn-buckle on the shaft served to press it out and hold it in position against the sides of the sewer.

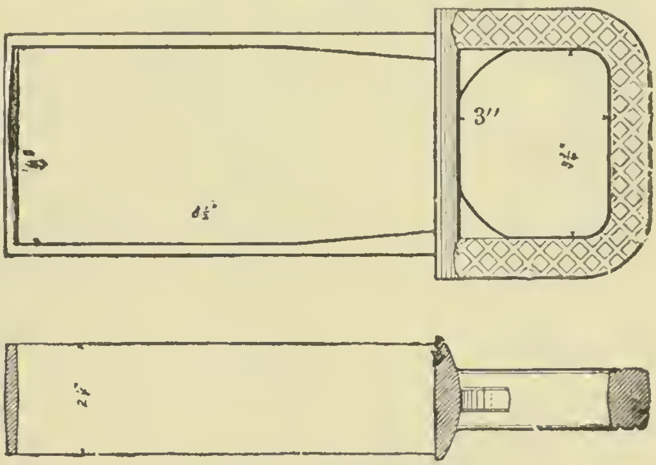


FIG. 207a.—MANHOLE STEP.

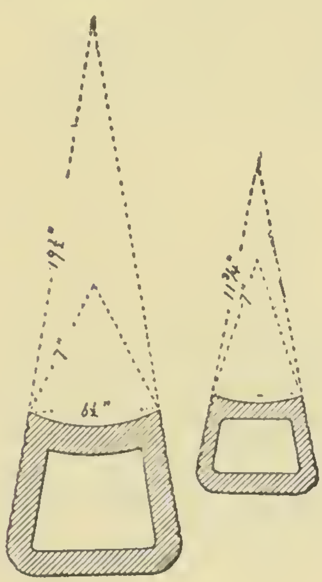


FIG. 208.—INVERT BLOCK.

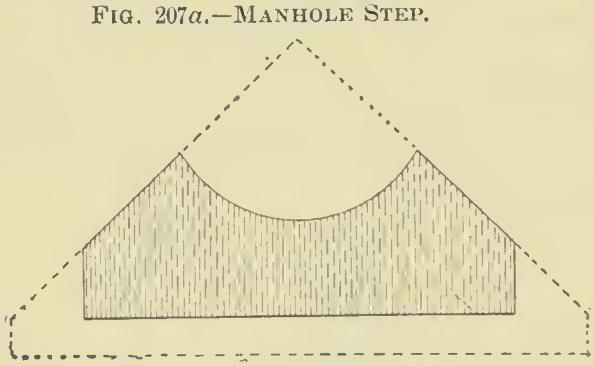


FIG. 209.

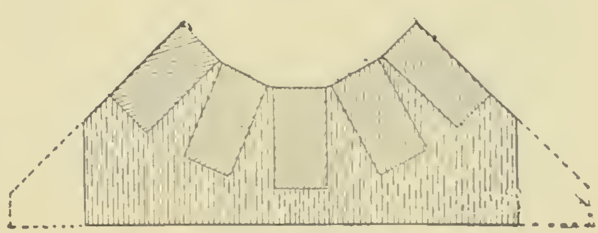


FIG. 210.

In operating this apparatus the derrick is set up over the man-

hole where the material is to be removed; the pulley and frame are put in place, and a small line is then floated down from the manhole above. This line is caught at the manhole and used to

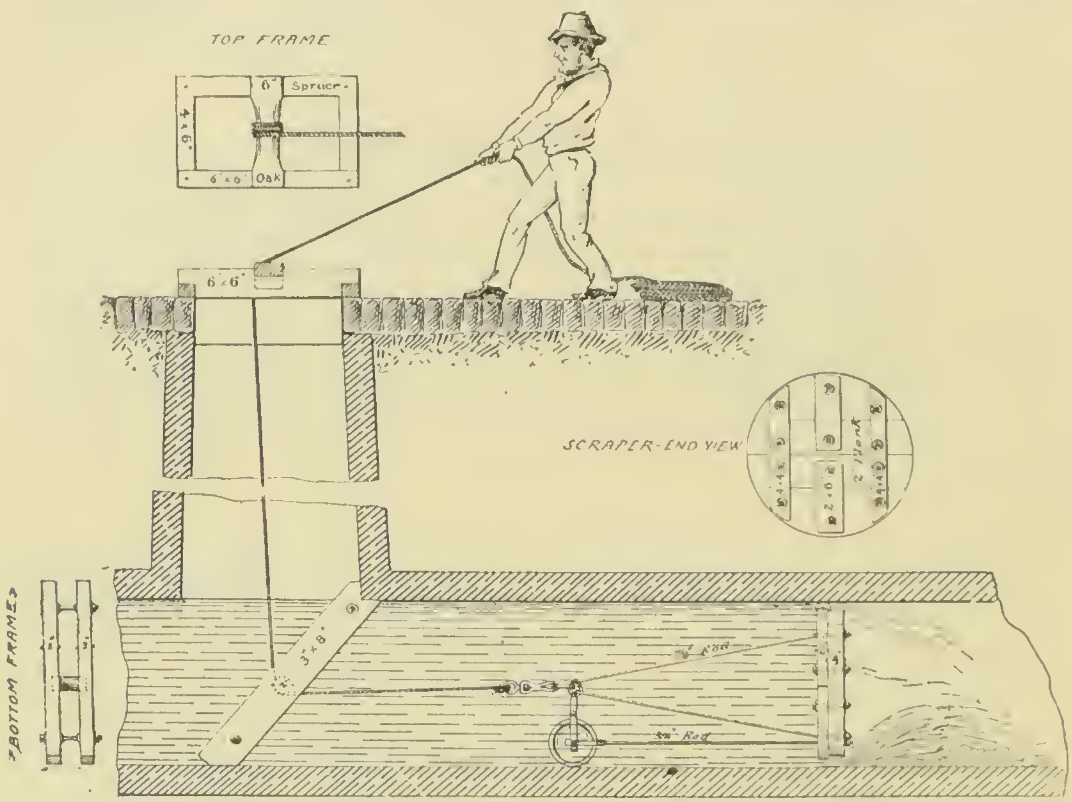


FIG. 211.—SMALL SEWER FLUSHING.

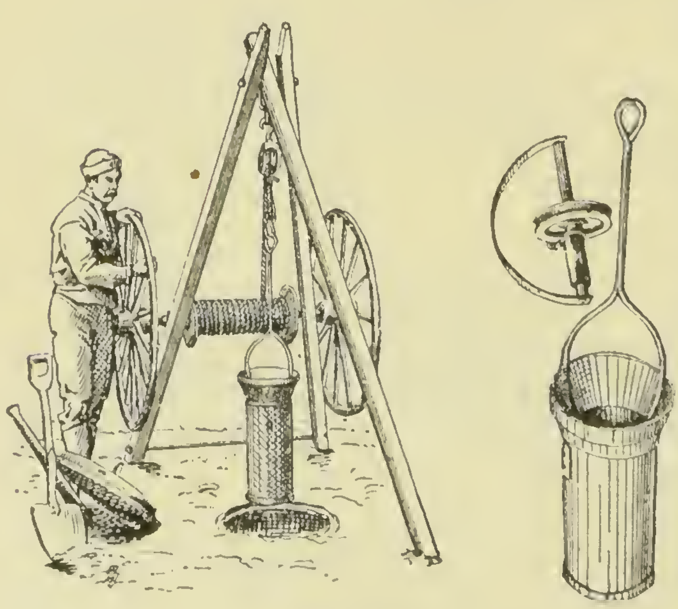


FIG. 211*a*.

draw the hauling rope to the upper manhole; one end of this rope is then attached to the ring in the end of the bucket bail, and the other end to the drum on the derrick. Another rope is also tied to the ring on the scraper and let out as this advances, and is used to pull it back for a fresh load. When the sand is cleaned out from one section, the third leg of the derrick is folded down upon the drum, the ropes, bucket, and pulley loaded

on the derrick, and the whole is then trundled off to the next point of use on the two wheels which do other duty in operating the drum. It has been successfully used in pipe sewers, and Mr. WELD said that they have had no difficulty in passing around curves.

The Hitchcock Sewer Inlet Trap.—The purpose of the trap shown in Fig. 211*b* is to prevent the escape of gases from the sewer through an inlet in the cooler seasons, when the air in the sewer is usually warmer than the air in the streets.

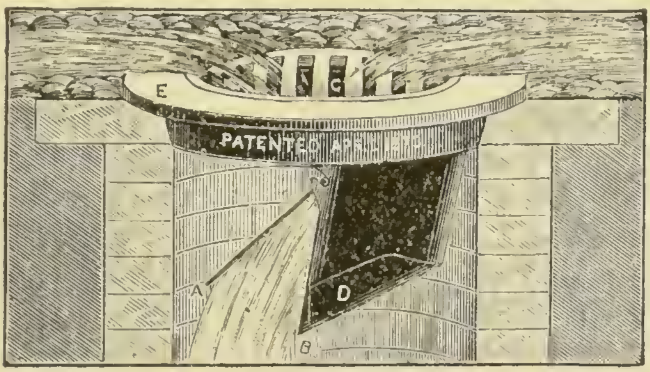


FIG. 211*b*.

The device explains itself. The lid, *A*, opens and permits the discharge of water entering the inlet; but at other times it remains tightly closed by its own weight against the fixed spout *D*. This trap is made of cast iron, and has been successfully used in Springfield, Mass., for about 15 years. It is manufactured by the Springfield Foundry Co., of that city.

A diagram illustrating the standard system of drainage in Providence, R. I., is given in Fig. 212. This is a cross-section

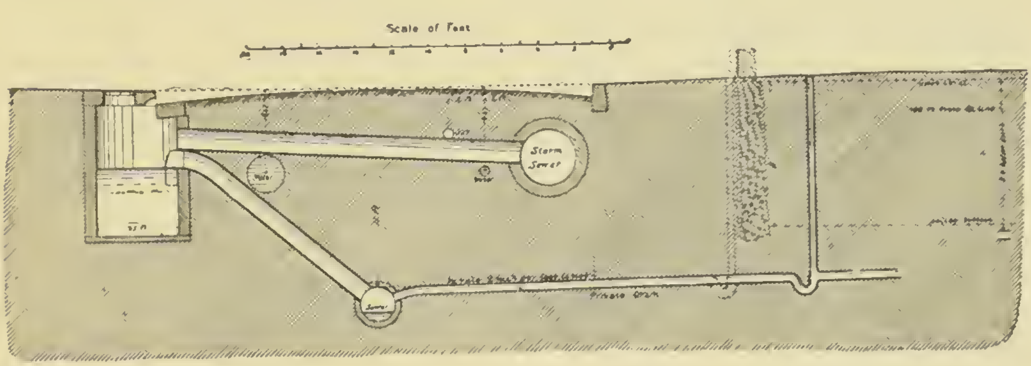


FIG. 212.—SECTION ILLUSTRATING DRAINAGE.

of a typical street, showing the location of the catchbasin, sewer and storm sewer, house connections, and water and gas pipes. The diagram is self-explanatory. It should be mentioned that in this city the ruling depth of sewers from street grade to the inside crown of the sewer has been fixed at 11 ft., and over 30

miles of sewers have been built in accordance with this rule. The 11 ft. was adopted because it permitted the private drain. laid at the minimum slope permitted (see rules and regulations for private drains), to reach a point 100 ft. from the street line and still be below the level of the curb.

Miscellaneous Tables and Rules, for Sewers and Drains.

Table Showing Size, Relative Capacity, and Material Required for Various Sizes of Sewers, Washington, D. C.

Size.	Area, sq. ft.	Hydraulic radius.	Relative capacity.	Concrete, cu. ft.	Brick masonry, cu. ft.	Pipe, size in ins.	Pipe, lin. ft.	Trap, in sq. ft.
12″	0 78	0.25	1.00	1.69		12	1.0	
15″	1.23	0.31	1.84	2.33		15	1.0	
18″	1.77	0.375	3.05	2.40		18	1.0	
21″	2.40	0.438	4.65	3.20		21	1.0	
24″	3.14	0.500	6.68	3.35		24	1.0	
2.0′ × 3.0′	4.64	0.567	10.81	3.88	4.680	12	0.5	
2.25′ × 3.37′	5.92	0.649	15.17	4.225	5.128	15	0.5	
2.50′ × 3.75′	7.23	0.700	19.40	4.165	5.521	15	0.5	
2.75′ × 4.12′	8 71	0 787	25 51	4.643	6.099	15	0.5	
3 0′ × 4.50′	10.41	0.857	32.46	5.360	6.620	15	0.5	
3.25′ × 4.87′	12.13	0.937	40.15	5.393	7.134	18	0.5	
3.50′ × 5.25′	14.10	1.010	49.26	5.622	7.683	18	0.5	
3.75′ × 5.62′	16.19	1.090	59.30	6.270	8.213	18	0.5	
4.0′ × 6.0′	18 54	1.150	70.69	6.347	8.624	21	0.5	
4.5′ × 6.75′	23.26	1.300	95.75	6.040	8.660			4.550
5.0′ × 7.50′	28.71	1 450	126.44	7.330	8.650			5.310
5.25′ × 7.87′	31.67	1.521	144.84	7.800	9.860			5.310
5.50′ × 8.25′	34.74	1.590	163.13	8.138	10 135			5.938
6.0′ × 9.0′	41.61	1.738	205.89	12.830	15.000			6.080
*6.5′ × 9.75′	48.53	1.882	254.60	15.612	16.832			6.768
†6.5′ × 9.75′	48.53	1.882	254.60	26.350	7.270			6.768
7.0′ × 10.50′	56.27	2.027	309.25	14.730	17.160			7.770
*10.0 circ.	78.54	2.500	493.03	17.376	27.598			10.470
†20.0 "	314 16	5.000	3016.73	130.421	28.512			15.908

* Brick arch. † Concrete arch.

Rules and Regulations for Private Drains Adopted by the Board of Public Works of Providence, R. I., May 27, 1882.

1. Applications for permits to connect with any sewer must be made in writing to the Board of Public Works by the owners of the property to be drained, or by their duly authorized attorneys, and must be accompanied by a clear description of the premises to be drained and of the drains required, and also by certain agreements, all as provided in the printed form of application issued by said Board.

2. No one but a drain layer duly licensed by the Board of Public Works will be allowed to make connection with the sewers,

nor lay any drains in connection therewith; and any person so licensed shall give personal attention to any work done under his license. He shall also employ none but competent persons to do said work.

3. Notice must be given at the office of said Board 24 hours, if required, before any street or public way can be opened for the purpose of laying a private drain, or before any drain pipe can be extended from work previously done and accepted, or new connections of any kind be made with such work, unless otherwise permitted by the City Engineer.

4. No work of laying drains can be commenced or continued unless the permit is on the ground, in the hands of the drain-layer or some one employed by him.

Rules for Laying Drains.—1. In opening any street or public way, all materials for paving or ballasting must be removed with the least possible injury or loss of the same, and, together with the excavated materials from the trenches, must be placed where they will cause the least practicable inconvenience to the public. As little as possible of the trench must be dug until the junction piece into the sewer is found, unless it is first determined to make a new opening into the sewer.

2. Whenever, in the opinion of the City Engineer or authorized inspector, the sides of the trenches will cave, sheeting and braces must be used to prevent caving.

3. The Board of Public Works, the City Engineer, and their authorized agent are to have at all times facilities for inspecting the work and materials while under the charge of the drain layer; and, if required, no pipe or other materials for the drains can be used till they have been examined and approved.

4. The least inclination that can be allowed for water closet, kitchen, and all other drains of not over 6 ins. diameter, liable to receive solid substances, is $\frac{1}{2}$ an in. in 2 ft.; and for cellar or other drains, to receive water only, $\frac{1}{4}$ of an in. in 2 ft. The depth of the crown of a drain at the curb line shall be determined by a rise of $\frac{1}{4}$ of an in. per foot from the crown of the sewer directly opposite.

5. The ends of all pipes not to be immediately connected with are to be securely stopped by brick and cement or other water tight and imperishable materials.

6. All pipes that must be left open to drain cellars, areas,

yards, or gardens must be connected with suitable catch-basins, the bottoms of which must not be less than $2\frac{1}{2}$ ft. below the bottom of the outlet pipe, the size, form, and construction of which are to be prescribed by the officers named in the second rule. When meat-packing houses, slaughter-houses, lard-rendering establishments, hotels, or eating-houses are connected with the sewers, the dimensions of the catch-basins will be required to be of a size according to the circumstances of the case. When the end of the drain pipe is connected with a temporary wooden catch-basin for draining foundations during the erection of buildings, the drain layer will be held responsible for dirt or sand getting into the drain or sewer from such temporary catch-basin.

7. No private catch-basin can be built in the public street, but must be placed inside of the line of the lot to be drained, except when the sidewalks are excavated and used as cellars.

8. Unless special permit shall be granted by the Board of Public Works, no privy vaults can be connected with the sewers except through an intervening catch-basin, and the discharge pipe of the vault must be high enough above its bottom to effectually prevent anything but the liquid contents of the vault from passing into the drain.

9. The inside of every drain, after it is laid, must be left smooth and perfectly clean throughout its entire length; and to insure the same a scraper of suitable material, of the shape of the pipe and slightly less in diameter, shall be drawn through each length of pipe after the same has been laid.

10. In case it shall be necessary to connect a drain pipe with a public sewer where no junction is left in such sewer, the new connection with such sewer can only be made either by one of the employés of the Board of Public Works or when an officer, named in rule two, is present to see the work done.

11. Whenever it is necessary to disturb a drain in actual use, it must in no case be obstructed without the special direction of one of the officers named in rule two.

12. The back-filling over drains, after they are laid, must be puddled or solidly rammed, and together with the replacing of ballast and paving must be done within 48 hours after the completion of that part of the drain lying within the public way, and done so as to make them at least as good as they were before they were disturbed, and to the satisfaction of the Board

of Public Works and the officers mentioned in second rule; and the owner will be held responsible for any settlement of the ground which occurs within one year on account of laying said drain. All water and gas pipes must be protected from injury or settling, to the satisfaction of the Engineer.

13. Every drain layer must inclose any opening which he may make, in the public streets or ways, with sufficient barriers, and must maintain red lights at the same at night, and must take all other necessary precautions to guard the public effectually against all accidents from the beginning to the end of the work, and can only lay drains on condition that he shall use every precaution against accidents to persons, horses, vehicles, or property of any kind.

14. In case a water or gas pipe should come in the way of a drain, the question of passing over or under the water or gas pipe, or of raising or lowering it, must be determined by one of the officers named in rule two.

15. All exhausts from steam engines and all blow-offs from steam boilers must be first connected with a catch-basin of such dimensions as the officers mentioned in second rule may prescribe; and in no case will they be allowed to connect directly with the private or public sewers without special permission from the Board of Public Works or the City Engineer.

16. Such information as the City Engineer has with regard to the position of junctions will be furnished to drain layers, but at their risk as to the accuracy of the same.

17. When any change of direction is made in the pipe, either in a horizontal or vertical direction, curves must be used. No pipe can be clipped contrary to the direction of officers mentioned in rule two.

18. All persons are required to place an effectual trap in the line of drain just before it leaves the premises, and to make an open connection with a down-spout back of the trap; also, when possible, to make an open connection with the highest part of the soil-pipe within the premises through a large pipe or flue, to a point above the roof of the building, unless special permit to vary from the same shall be granted by the Board of Public Works.

19. The drain layer shall faithfully observe all the rules for laying drains as adopted by the Board of Public Works, and, if so directed, shall not cover any of his work until it has been examined and accepted by the proper officer.

20. No drain layer or person employed by him will be allowed to rest any planking or other material upon any gas or water pipe. Violations of this rule will be sufficient cause for the revocation of license.

21. The drain-layer who obtains the permit shall carefully fill out the blank return provided, whether for new work or for alterations or additions, and return the same within 48 hours after the completion of said work.

22. All work shall be done in such manner and at such times as to interfere as little as possible with the public travel and convenience; and the drain-layer shall conduct his work for this object as the Engineer may from time to time direct.

23. Every person violating any of the provisions of the foregoing rules shall be liable to pay a fine of not less than twenty nor more than fifty dollars, and shall be subjected to a forfeiture of his license.

Rules for Finding Number of Bricks in Circular and Egg-Shaped Sewers.

Mr. MEADOWS, of the Canadian Society of Civil Engineers, gives the following rules for the above, with brick $8\frac{1}{2} \times 2\frac{1}{2} \times 4$ ins., and $\frac{1}{4}$-in. joints:

For circular sewers, multiply the internal diameter of sewer in inches by 1.1421 to find the number of bricks in first ring. Then add 10.28 inches to the internal diameter for each additional ring.

For circular sewers

$$\left\{ (d_1'' \times 1.1421) + [(d_2'' + 10.28) \times 1.1421] \right\} \times \text{length in ft.} \times 1.37144 = \text{number of bricks in sewer.}$$

For egg-shaped sewers, multiply the internal transverse diameter of the sewer in inches by 1.4418 for the first ring, and add 10.28 inches to the internal diameter, as before, for each additional ring.

NOTE.—The most usual way is to calculate the number of cubic feet of masonry in the sewer. See Washington, D. C., p. 252.

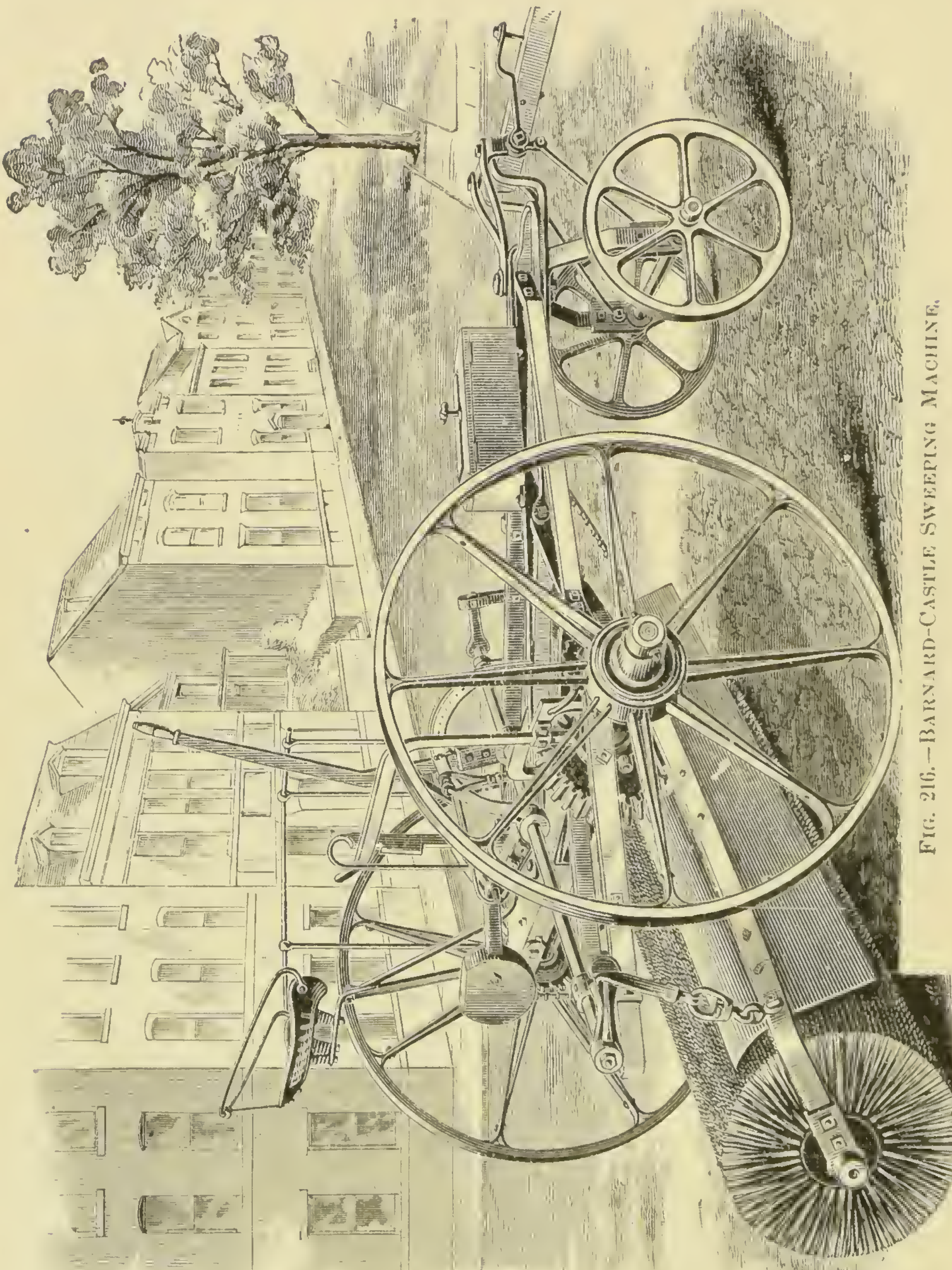


FIG. 216.—BARNARD-CASTLE SWEEPING MACHINE.

STREET CLEANING.

SWEEPING MACHINES.

At the time this series of articles on "Municipal Engineering" was prepared (1885) the sweeping machine in use in Boston was that known as the STACKPOLE (Fig. 213). While the illustration shows a one-horse sweeper, other machines in use by the department were fitted with a pair of front wheels and a pole, and were pulled by two horses. The reason given for the greater economy of the latter machine was that two horses can work in such a machine all day, while in the smaller sweeper one horse can only work one-half day, and time is lost in the change.

Rattan is used in the broom instead of the usual "bass"; and while this rattan is more expensive, it is found to be much more efficient in handling slush in winter, in sweeping gravel from the railway tracks, cleaning crossings, etc. The rattan (in 1885) cost 30 cts. per pound, as compared with "coir grass," or "bass," at 12 cts. per pound.

The sweepers used in Providence, R. I. (Fig. 214), are made by the ABBOTT DOWNING CO., of Concord, N. H. But in this case a third wheel and a pole is added, adapting them to use with two horses.

Figs. 215 and 215*a* show the "Capital" sweeping machine, invented by L. P. WRIGHT, of Washington, D. C., and was used by him when he had the contract for cleaning that city. This machine is made entirely of iron, except the wheels, and is made heavy so as to remove all dirt from the depressions in the pavement, car tracks, etc. It is pulled by four horses and sweeps from the center of the street, to the right, into the gutter.

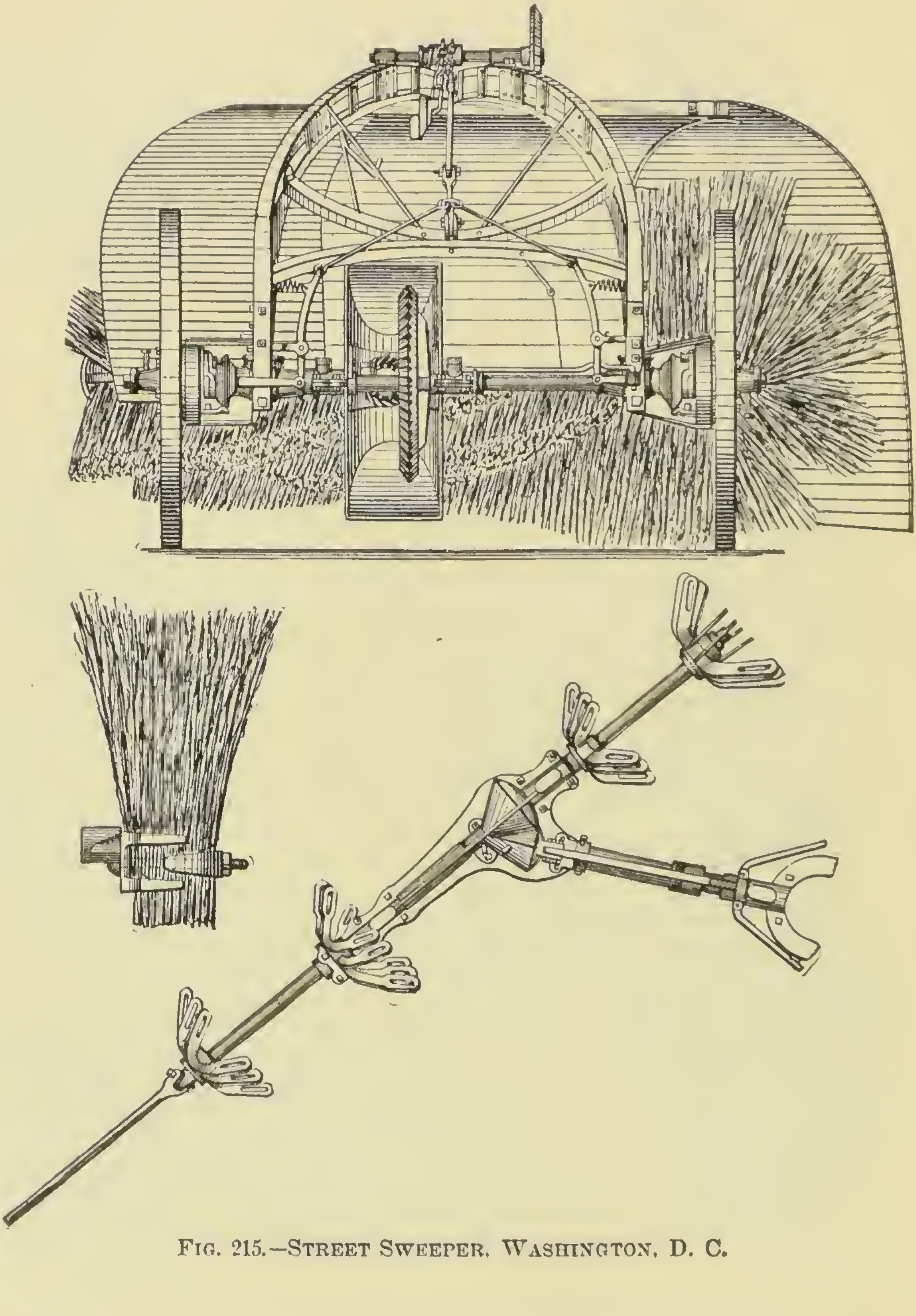


FIG. 215.—STREET SWEEPER, WASHINGTON, D. C.

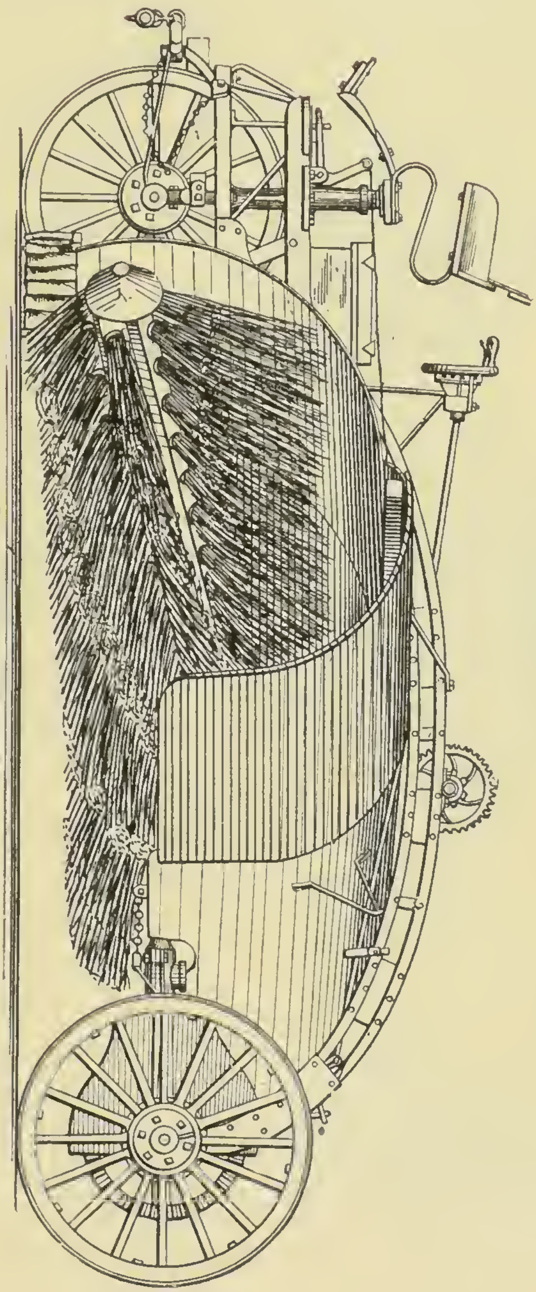


FIG. 215*a*.—STREET SWEEPER, WASHINGTON, D. C.

The broom, which makes an angle of 45° with the axis of the machine, is 12 ft. long, and sweeps a path 9 ft. wide. When new this broom is 5 ft. in diameter, and, with the broom shaft, it weighs 650 lbs. The broom is made of 96 bunches of white birch twigs, and is worn down to 2 ft. in diameter before it is renewed. The whole broom is hung at the center so that it can readily adjust itself to any uneven surfaces or in crossing a street. This machine sweeps 125,000 sq. yds. in 10 hours.

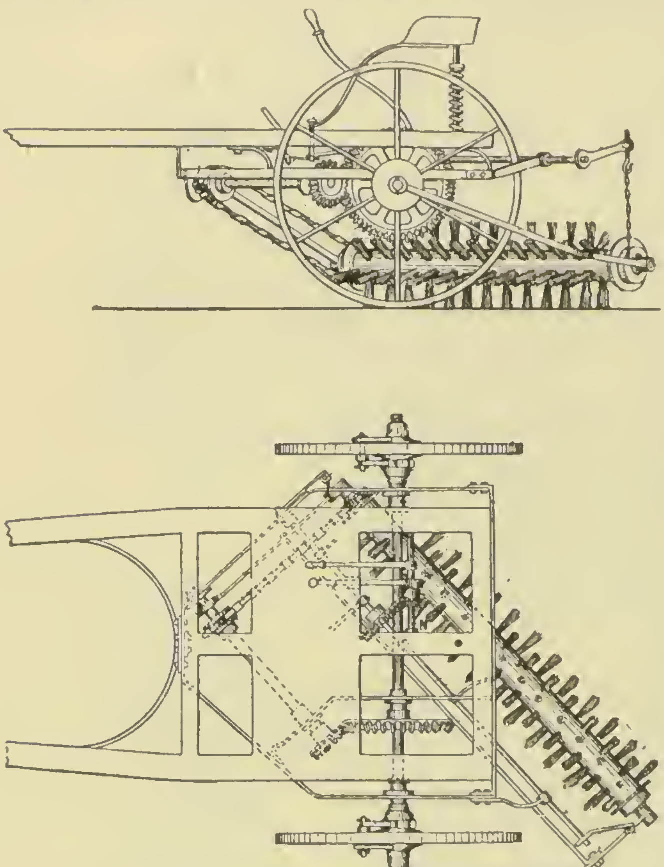


FIG. 213.—STACKPOLE STREET SWEEPER.

The city of London uses about 2,000 of the sweeping machines shown in Fig. 216, page 258. This is the so-called BARNARD-CASTLE machine. The frame is built almost entirely of wrought iron, and it is durable, light and handy. Several sizes are built; one, to be used with one or two horses, will sweep a path 6 ft. wide; and the other is a heavier machine requiring two horses and sweeps $7\frac{1}{2}$ ft. wide. The cut illustrates the latest form of the machine, which sweeps $7\frac{1}{2}$ feet wide. The broom in this machine has a universal joint in the center to compensate for inequalities in the pavements. In his treatise on the scavenging and cleaning of towns, Mr. H. PERCY BOULNOIS, M. Inst. C. E., says that a 6-ft. machine will sweep from 8,000 to 10,000 sq. yds. per hour in fair work. He further says that it costs little for repairs, and that one set of brushes (costing about $10) will last during 180 hours of constant work.

This machine is now sold in the United States by W. C. OASTLER, 43 Exchange Place, New York, the American representative of the makers.

STREET SPRINKLING.

What may be called a very common form of street sprinkling machine in American cities is shown in Fig. 217, page 266, in longitudinal section, rear cross-section, and front view. This is the so-called "Monitor" type of sprinkler, made by the ABBOTT DOWNING Co., of Concord, N. H.

A street-scraping machine made by L. P. WRIGHT & SON, of Washington, D. C., is shown in Fig. 217*a*. It is used for collecting

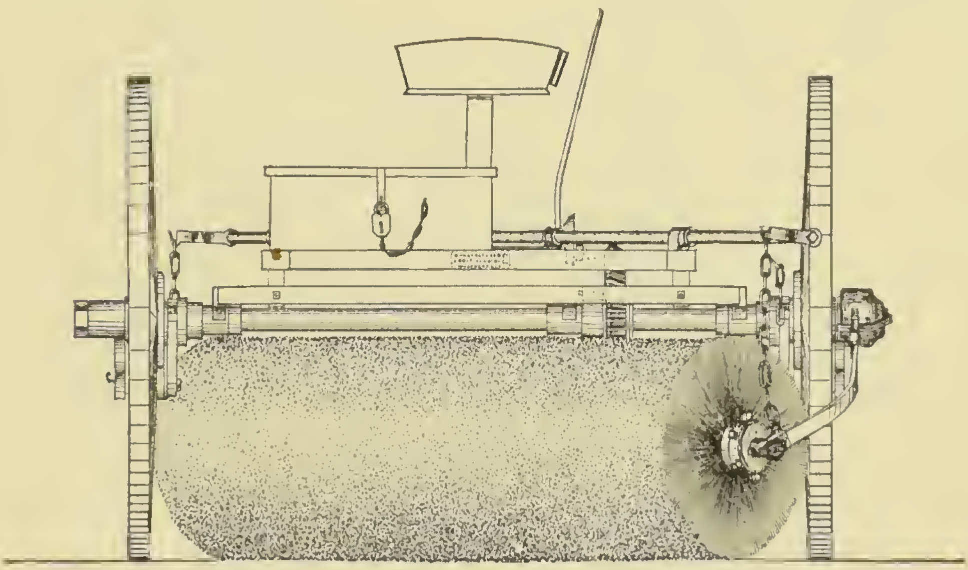
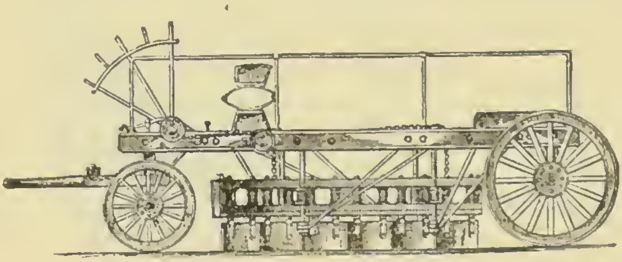


FIG. 214.—STREET SWEEPER, PROVIDENCE, R. I.

snow or mud from the streets, in cases where this mud is too deep and heavy for a sweeping machine. The machine has an iron frame with 12 steel shovels beneath the body, arranged diagonally, and pressed down against the pavement by strong springs. With 4 or 5 horses to pull it, the claim is made that this machine will do the work of 200 men with hoes. In a thaw the plows can be reversed and the machine used to scrape snow from the gutters toward the middle of the street, so as to allow the water to run off.



(Street Scraper, pat'd May 20, 1873.)

FIG. 217*a*.

Sea Water for Street Sprinkling.—A paper upon this subject was read in 1889 before the Civil and Mechanical Engineers'

Society of England by Mr. S. H. TERRY. Inquiries were sent out to the engineers of 35 coast towns in England that had used sea water for sprinkling the streets. The answers showed that 23 of these towns had abandoned its use, for various reasons.

The Ramsgate and Folkestone engineers said that it destroyed all kinds of road material except wood. Some towns advised its use in sewer-flushing, but others thought it produced obnoxious gases when brought into contact with sewage.

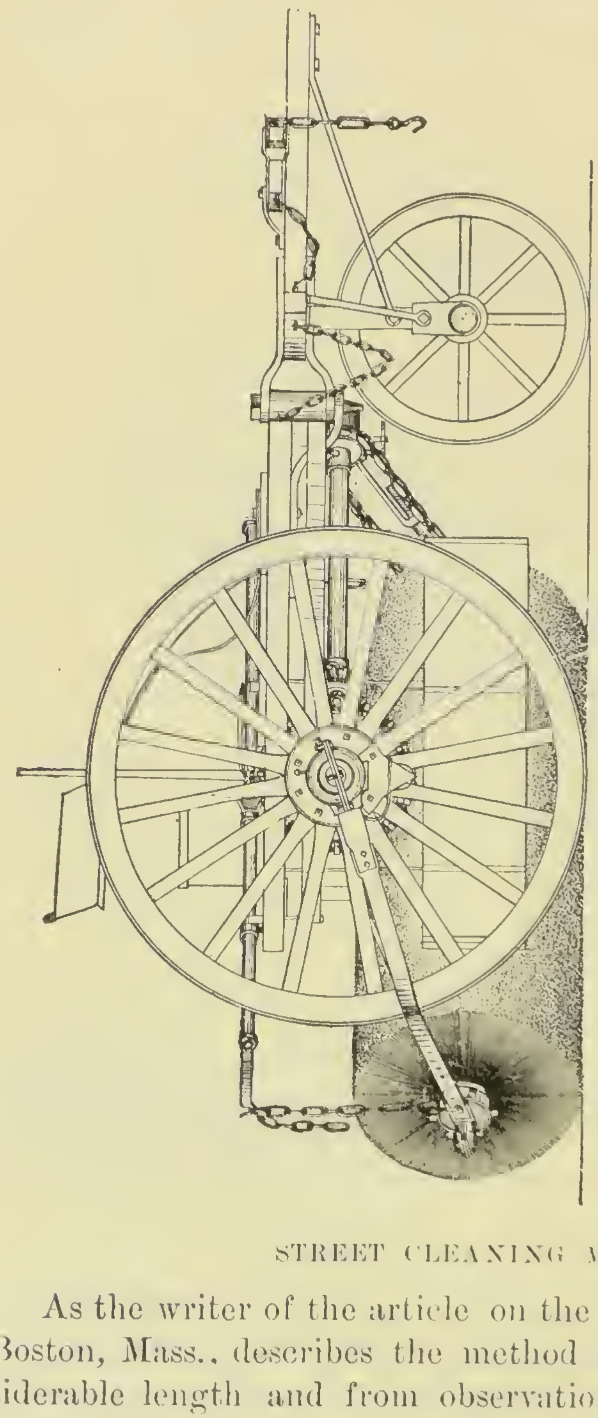


FIG. 214a.

On roads of flint and gravel the application of sea water doubtless prevents dust, and Berwick-on-Tweed highly commends it for this purpose. The engineer of that town found that one cart of seawater was equal to two of fresh water for this purpose.

The town of Bournemouth, Eng., found salt water particularly advantageous for macadamized roads, as "it seemed to make the immediate surface more compact." It was found there that the surface held the moisture almost three times as long with salt as with fresh water.

STREET CLEANING METHODS.

As the writer of the article on the municipal engineering of Boston, Mass., describes the method of street cleaning at considerable length and from observation of actual practice, this matter is practically reprinted here, as follows :

Taking a street of average width as an example, and few of the old Boston streets are wide, work commences at such an hour in the morning in the business portion of the city that the streets are cleaned and the dirt removed by 7 A. M. In the operation of cleaning, a city watering-cart first passes over the ground. This cart differs from that ordinarily used in street sprinkling in having finer jets or openings to the sprinkler. After this cart usu-

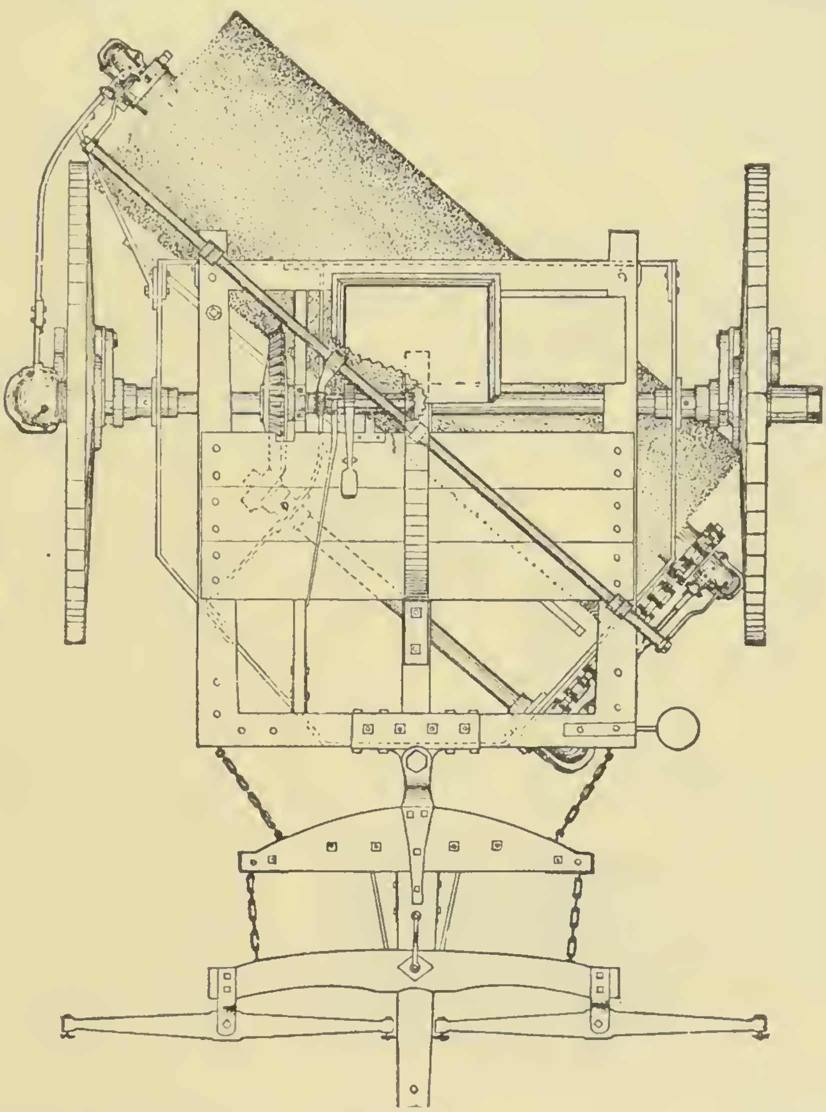


FIG. 214b.

ally follow two one-horse sweeping machines, moving in *echelon* in the narrower streets, so as not to obstruct travel. Commencing in the middle of the streets, these two machines sweep the dirt toward the gutters, making several turns over the block if the width of the street requires it. The dirt thus collected in long rows is then roughly gathered into piles by two men, one on

each side of the street, with a distance between piles regulated by the quantity of dirt swept up. Two other men follow in each gutter, and, with ordinary birch brooms, sweep clean the intervals between the piles and clean out such angles as the sweeping machine itself cannot reach. Finally come one-horse carts, with two men to each. One of these men shovels the dirt into the cart and the other assists him in filling his shovel by handling the special carter's broom shown in Fig. 218.

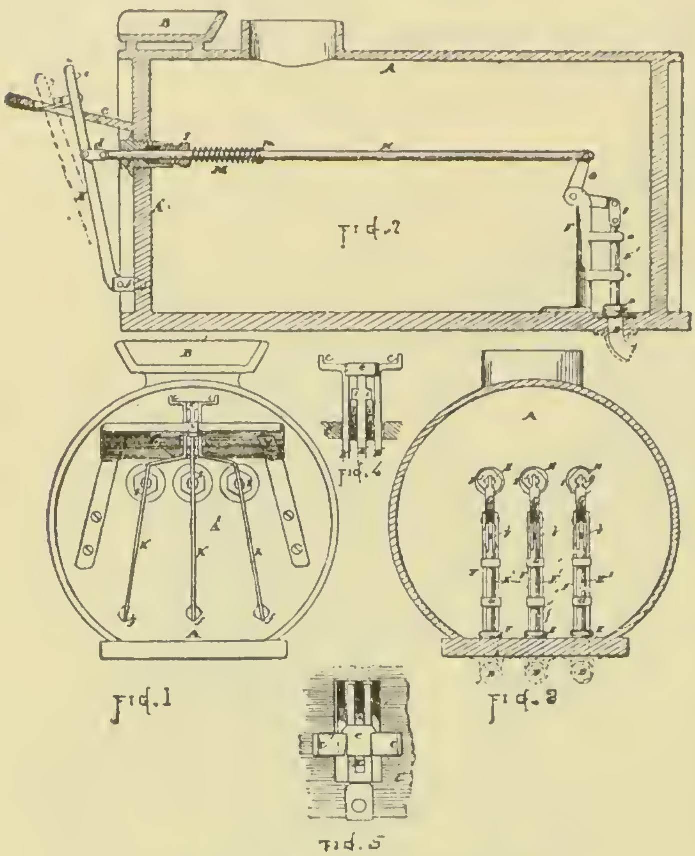


Fig. 217.—Monitor Sprinkler.

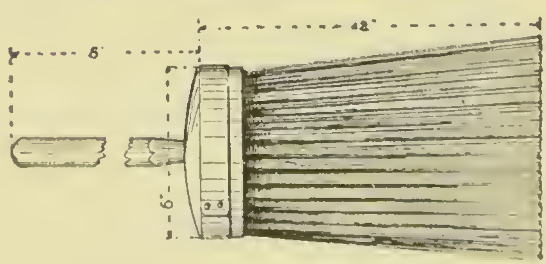


Fig. 218.—Teamster's Broom

In Boston (in 1885) all street cleaning was done by the city with its own men, horses, and machines. The working force consisted of 181 men (87 being sweepers), 34 carts, 10 sweeping-machines, and 6 watering-carts. With this force an average of 185 miles of streets were cleaned each week. All principal streets were swept daily, and the others twice a week. The quantity of street dirt removed in the year mentioned was 92,180 cu. yds., and the amount paid out in the year for labor was $97,280.10.

The wages paid per day in 1885 were as follows: Teamsters, $2.10; teamsters' helpers, $2.02; drivers of sweeping-machines, $2.10; sweepers and their helpers, $2 each. The men employed were selected for their fitness only, young married men having the

preference. At the time this Boston article was prepared, the Superintendent in charge of this department had been in office over 20 years, and the permanency of employment for good men, inaugurated by him, had made positions in the department so desirable that, having many to select from and being free to choose for himself, only the best of the applicants received appointments. This method of handling a city office is so rare at the present day that the Boston method, here described, is worthy of especial note. Whether that city conducts its work now on similar lines is not known.

The daily cost in 1885, without a driver, was $2 for watering-cart; $4.40 for a one-horse sweeper, allowing for one horse in the morning and another horse in the afternoon; $4.75 for a two-horse sweeper, using both horses all day, and $2.10 each for ash carts and offal wagons.

For the purpose of itemizing the cost of street cleaning in the summer season the following figures were deduced from the actual records of the department for cleaning a street 66 ft. wide between curbs and over a length of 8,385 ft. The total time occupied in cleaning this area of 553,410 sq. ft was 2 hours 45 minutes:

No. employed.	Class of labor.	Cost per hour.	Total hours.	Total cost.
1	Watering cart	$0.20	2.75	$0.55
1	Driver	.21	2.75	.57¾
3	Sweeping-machines	.44	8.25	3.63
3	Drivers	.21	8.25	1.73¼
6	Men with hoes	.20	16.50	3.30
12	" " brooms	.20	33.00	6.60
8	Carts	.21	22.00	4.62
8	Teamsters	.21	22.00	4.62
8	Teamsters' helpers	.20⅕	22.00	4.44⅗
	Total cost of sweeping 553,410 sq. ft			$30.07⅗

At the above rate the cost of cleaning per 1,000 sq. ft. was $0.054; or one mile of this 66-ft. street cost $18.81½ to clean.

In Providence, R. I., all street-cleaning work is also performed by the employees of the city department. The work here is divided into three divisions, viz.: Paved streets swept by a daily patrol, paved streets swept by horse machines, and unpaved streets. The streets swept by the daily patrol lie in the center of the business portion of the city and aggregated in 1885

about 117,711 sq. yds.; those swept by machines, about 341,214 sq. yds., are each cleaned once a week, and a gang with two two-horse sweeping-machines are at work every night when the weather is favorable; the cleaning of the unpaved (macadam or gravel) streets, aggregating about 88 miles in length, is performed by one gang that averages about 9 circuits a year over this length of streets. Main thoroughfares, however, are cleaned oftener than this when required.

The streets of Washington, D. C., were (in 1885) cleaned by contract at the rate of 28½ cts. per 1,000 sq. yds. for sweeping, cleaning, and disposal of sweepings. It should be remembered, however, that Washington at that time had only 175,316 sq. yds. of granite pavement out of a total of 719,796 sq. yds.; the rest of the pavement was asphalt, with a small area of asphalt block.

Snow Removal and the Use of Salt for this Purpose in Paris.—In an article on "Street Cleaning in Paris," Mr. H. VIVAREZ says that it is only since 1870 that any exact regulations have been adopted fixing the relative proportion of work to be performed by the city and the citizens in removing snow and ice from the streets. The snow is heaped up by individuals and by the scavengers, and is then removed by contract at a fixed price per cu. metre.

By its charter the *Compagnie des Omnibus* is obliged to furnish 50 carts, with two horses each, for this service. The price paid in each section for hauling is fixed by the length of haul to point of discharge. The quantity is arrived at either by an estimate of the heap, or by the capacity of the cart.

When a thaw takes place the hydrants are opened, and both brooms and sweeping machines are used to sweep the melting snow into the sewers. In 1879-80, M. D'USSEL introduced the use of salt, in an unusual fall of 10 to 14 ins. of snow. He treated 210,000 sq. yds. of roadway with 55,000 lbs. of salt, with excellent results. The salt was scattered by a man from a barrow; and the proportion used for 1 to 2 ins. of snowfall was 0.37 lbs. per sq. yd. If the depth of snow amounted to 6 or 8 ins. the application was made twice and the surface snow removed in the interval.

With salt at 2 cts. per lb. (including the *octroi* and state tax) the cost of applying it to the streets, in the above propor-

tions, was about $\frac{3}{4}$ cent per sq. yd., which is about one-half the cost of sanding the streets of Paris. An attempt to substitute the cheaper chloride of calcium for the salt was abandoned, owing to its acid reaction and because it stained the clothes of pedestrians. Between Dec. 8, 1885, and Jan. 25, 1886, snow fell in Paris seven times, in each case to a depth of 4 ins. Thanks to salting, the snow, in each case, was removed the same evening and traffic was uninterrupted. The salt amounted to 1.7 per cent. of the snow by weight. The actual cost of snow removal by salt, in the month of January, 1886, was $71,300 ; whereas by the ordinary method it would have cost, in Paris, more than $300,000.

GARBAGE REMOVAL.

The removal of ashes, garbage, etc., in the city of Boston is one of the duties of the department presided over by the Superintendent of Health, an officer appointed annually by the Mayor, and who is also responsible for the cleaning of streets, city catch-basins, etc., as already described.

In the removal of this refuse one of the first requirements of the city ordinance is that no ashes or house rubbish shall be mixed with the animal or vegetable waste usually called "swill." The two classes of refuse must be kept separate; the ashes generally in metallic tubs, to guard against danger from fire, and the swill in tight vessels. These receptacles "must be located in an easily accessible place" on the premises, and in Boston this is usually in the yard. The city scavengers must remove them from the yard and return the empty vessels to their proper place.

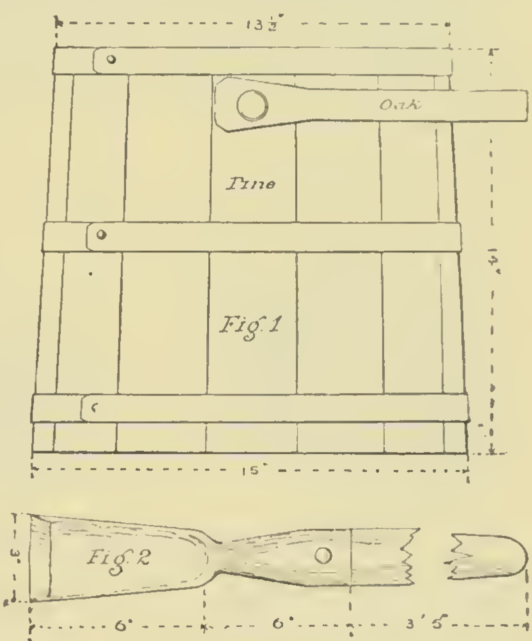


FIG. 219.

The swill is removed daily from all hotels, markets, restaurants, and other points of rapid accumulation. From dwelling-houses

it is taken away three times a week in summer time and twice a week in winter.

For the purposes of collection the city of Boston is divided into 49 districts, to each of which is assigned one swill wagon, a driver and a helper. With each wagon are two offal buckets (Fig. 219) in which the swill is transferred from the house receptacle to the wagon. The chisel shown on the same figure is used in chopping frozen matter from the house tubs.

The swill wagons have a thoroughly water-tight body, containing about 64 cu. ft., and are closed on top by tight, hinged wooden covers. There is absolutely no dripping from them or offensive odor, and they are thoroughly washed inside and out after discharging each load.

The collection is made during the whole day, up to 5 P. M., and the daily average of each wagon is from two to three loads, depending upon length of haul. The swill is taken to one of three city depots, in Boston, Roxbury and Charlestown, and is there dumped out on tight, raised platforms, where it is sold to farmers, who remove it. The prices paid for this swill varied in 1885 from $4 to $6 per "cord" of 128 cu. ft., the price depending upon the distance the farmer had to haul it: the nearer to his farm the higher the cost.

In the official year of 1884–85 the city of Boston employed in this service 108 men and 49 swill wagons. This force collected in the year 28,520 loads, or, averaging the load at 60 cu. ft., a total of 63,400 cu. yds. of swill. The sum of $87,691.93 was expended for labor, and the amount realized from the sale of swill was $36,420.52.

For the collection of ashes and house dirt Boston is divided into 76 fixed routes, to each of which is assigned one one-horse cart, a driver, and a helper. This class of refuse is removed from hotels, tenement-houses, and stores twice a week and from dwelling-houses once a week.

The ash carts have a capacity of about 44 cu. ft., and they must be covered with canvas while passing through the streets. The city employee must remove these ashes, etc., from the receptacle in the yard, but is not required to go up stairs for it. The usual practice is that, while the driver is taking a load to the city dump, his helper remains on the route and transfers the

ash tubs to the street ready for the next load. Each cart makes from 6 to 8 trips per day.

Whereas this refuse was for years utilized in filling in the low lands about Boston, these places of deposit are fast decreasing in area and number. Of late years the Barney dumping-scow (Fig. 220) has been used for taking this rubbish out to sea. This is the same scow employed by the New York authorities in the removal of city refuse. The price of one of these scows (in 1885) was \$12,000, and \$1,500 annually as a royalty.

This patent dumping-boat is 110 ft. long, 28 ft. wide, and 12 ft. deep. Its carrying capacity is about 500 tons, and when

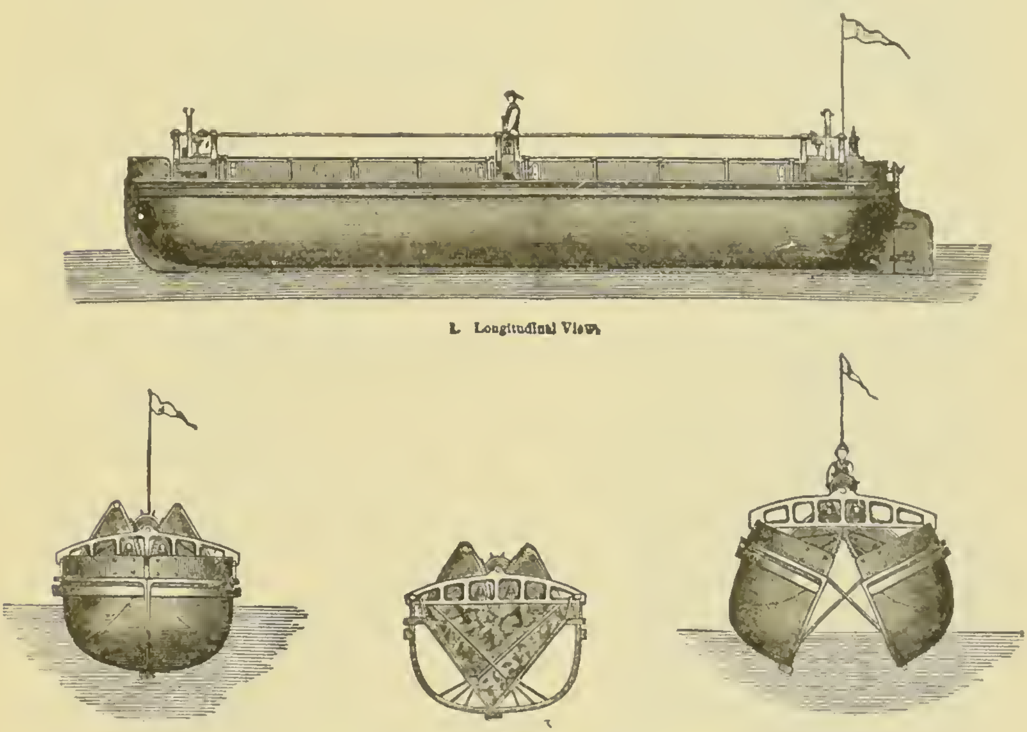


FIG. 220.—BARNEY DUMPING SCOW.

loaded it draws about 9 ft. of water. It is thoroughly seaworthy in construction, and two men will dump the load, wash out and close the boat, and be ready to return to port in from 5 to 10 minutes.

The illustration shows two strong half-hulls, or pontoons, secured together at each end and in the middle by heavy bridges hinged to its outboard shell. The storage hold is V-shaped. The fastenings at the three bridges are operated from one center wheel; and as soon as these are released the load forces the pontoons

apart and escapes at the bottom, and the empty pontoons automatically close, the movement being about one-eighth of a circle.

An official report of the Boston Board of Health stated that between June 1, 1884, and April 1, 1885, one of these scows had carried to sea and dumped 14,823 "loads." The board estimated that the saving to the city in horses, carts, and labor due to this change in method of disposal was $25,000 for the period named.

Catch-basins are cleaned by this same department as before mentioned. In this service a wagon is used, built in every respect like the swill-wagon before described. With each wagon are three men, one of whom fills the bucket (Fig. 221) at the bottom of the basin; another hoists the bucket by the hook, shown in the same cut, and the third empties contents of the bucket into the wagon. The material thus removed is usually hauled to one of the city dumps and covered with ashes.

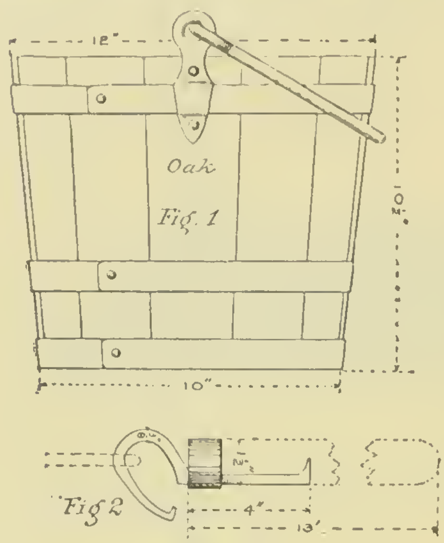


FIG. 221.

In Washington, D. C., garbage removal is performed by contract—daily from hotels, etc., and from dwellings three times a week in summer and twice in winter. The contractor is required to collect the swill or house refuse in barrels having a tight-fitting cover, and these are carried away on a low-hung wagon.

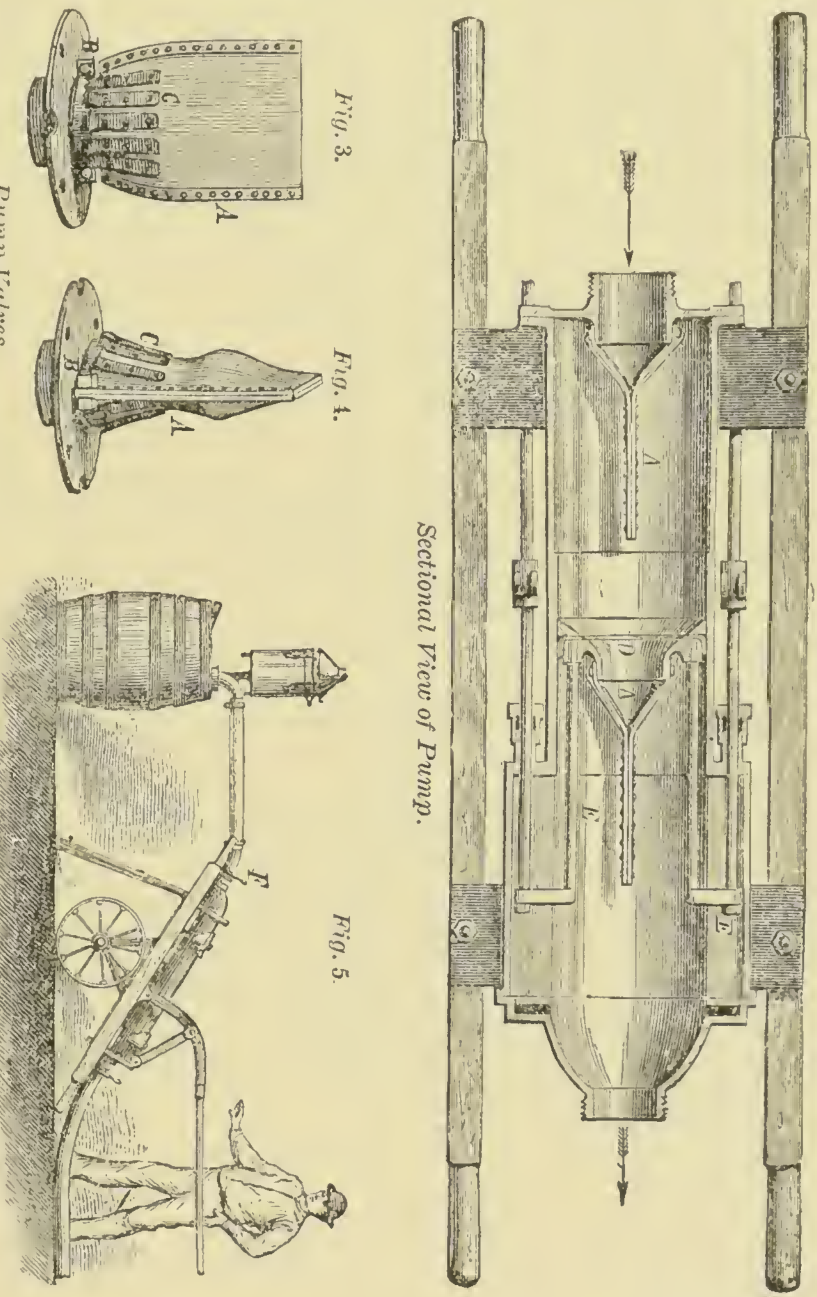
VAULT CLEANING.

The cleaning of vaults in the majority of American cities is performed by the so-called "OTIS odorless excavator," built under patents controlled by KEYSER & PAINTER, No. 44 Holiday St., Baltimore, Md. This company makes yearly contracts with a city and usually performs its work under the control of the Board of Health.

The regulations for the city of Boston will sufficiently outline the terms and conditions under which this service is performed. These are as follows:

The contracting company has the exclusive right for the contract period of removing the contents of all vaults in the city. The city receives and forwards all applications for cleaning, and

the contractor may demand from the owner of the premises the sum of $5 for every load of 80 cu. ft. removed, and the same sum if the vault contains less than 80 cu. ft. The contractor may



Sectional View of Pump.

Pump Valves.

Fig. 4 shows the Valve with an obstruction passing through it.

Apparatus as employed in Washington.

FIG. 222.—SMALL ODORLESS EXCAVATOR.

demand a deposit of money from the citizen to secure his fee.

This work is now most generally carried on in the daytime, without any offense whatever. The "excavator" is simply a very strong, air-tight, cylindrical tank mounted on wheels, with a capacity of about 80 cu. ft. This tank is connected with the

vault by a substantial suction hose admitting of a range of 150 ft. An air-pump on the tank provides the vacuum necessary for transferring the contents of the vault to the tank, and the gases are rendered inoffensive by passing them through a chemical compound, of which carbolic acid is the base. Stout barrels, with lids fitting tight, with screw-clamps and a gasket, are used in handling the more solid matter.

A modified form of apparatus made by the same company is shown in Fig. 222. This is a profitable machine used in connection with barrels. The chief novelty in this device lies in the form of the valves, which may be called upon to pass all manner of rubbish. This valve is made of soft, elastic, vulcanized rubber, with two flat pieces placed face to face and riveted along the two opposite edges. Its length is equal to about three diameters when open.

One end of this valve is distended by and is securely fastened to the collar shown, by clamps and bolts. The straps or braces at the mouth of the valve are intended to directly guard the post, and to prevent the elastic pipe from being forced into the post by external pressure. The pump itself is cylindrical and single-acting, with one fixed and one movable valve, the latter being operated by the two side stems shown, passing through stuffing-boxes.

As this valve is essentially a collapsible tube of greater length than diameter, and with one end permanently distended, any object that can pass through the induction opening must either pass through the inboard end of the valve or be held tightly on the valve (as shown in one of the cuts) until the inner end opens on the next stroke. The manufacturers state that in one case a large rope about 40 ft. in length was "pumped through with the greatest facility."

APPENDIX.

Diagrams of Hydraulic Formulas.

The hydraulic diagrams in the present edition were constructed by Messrs. Adams and Gemmell, and, with several others, appeared as an inset in Engineering News of April 27, 1893. They are intended to take the place of the diagram compiled by J. Leland Fitzgerald, M. Am. Soc. C. E., which was reproduced in the first edition, but which necessitated the insertion of a large folding plate.

These diagrams will not serve for all sewerage calculations which may be necessary, but should be taken by the engineer as a guide or indication of the manner in which other diagrams may be constructed to meet various conditions. For instance, diagrams for an elliptical section, or four-center ellipse, are often required. Then again, in practice it is desirable to have such diagrams on a larger scale than could be conveniently shown here. The engineer may also have some preference for the manner of indicating the slope ; an extremely useful way is to show it as a percentage of the length, *i. e.*, a fall of a certain number of feet per hundred. The discharge is given by these diagrams in cubic feet per minute, but it might perhaps have been better to have given it in cubic feet per second, which is the method generally adopted.

It must be borne in mind that although these diagrams are only intended to give "approximate" results, yet in practice no serious inaccuracy can be caused by their use, as any slight errors in plotting or drawing are well within the limit of error in the formula itself.

The following references to hydraulic diagrams which have appeared in Engineering News may prove useful to the engineer: "Diagrams of Various Hydraulic Formulas for Approximate Use," compiled by J. Leland Fitzgerald, M. Am. Soc. C. E., Sept. 6, and (correction) Sept. 13, 1890; "Flume and Ditch Diagrams," by A. L. Adams (of Adams and Gemmell), Feb. 13, 1892; "Diagrams for Flow in Pipe Sewers," by Prof. A. N. Talbot, M. Am. Soc. C. E., Aug. 11, 1892.

Reference may also be made to the sewer diagrams designed by Rudolph Hering, M. Am. Soc. C. E., given in his paper, "The Flow of Water in Small Channels," which may be found in Vol. VIII, Trans. Am. Soc. C. E., 1879.

Plate 1. *Discharge and Velocity of Flow in Pipe Sewers from* 6 *Inches to* 24 *Inches in Diameter.*—There are four different plottings on this plate, numbered for reference as Diagrams 1, 2, 3 and 4. All have been computed by Kutter's formula, using the coefficient of roughness "N" = 0 013. In Diagram 1 the inclination or slope, expressed as one in 200, 300, etc., having been taken on the left-hand vertical scale, the discharge in cubic feet per minute may be found on the top horizontal scale. In Diagram 2, the inclination being taken on the left-hand vertical scale, the discharge in cubic feet per minute may be found on the bottom horizontal scale. In Diagrams 3 and 4, the discharge in cubic feet per minute having been taken on the right hand vertical scales, the velocity in feet per minute may be found on the horizontal scale. If it be desired to use the coefficient "N" = 0.012, then 10% should be added to the results obtained by the diagrams.

Plate 2. *Discharge and Velocity in Circular Sewers Flowing Full.*—There are two plottings on this plate: Diagram 1 for discharge, and Diagram 2 for velocity. They have been computed by Kutter's formula, using "N" = 0.013. In Diagram 1

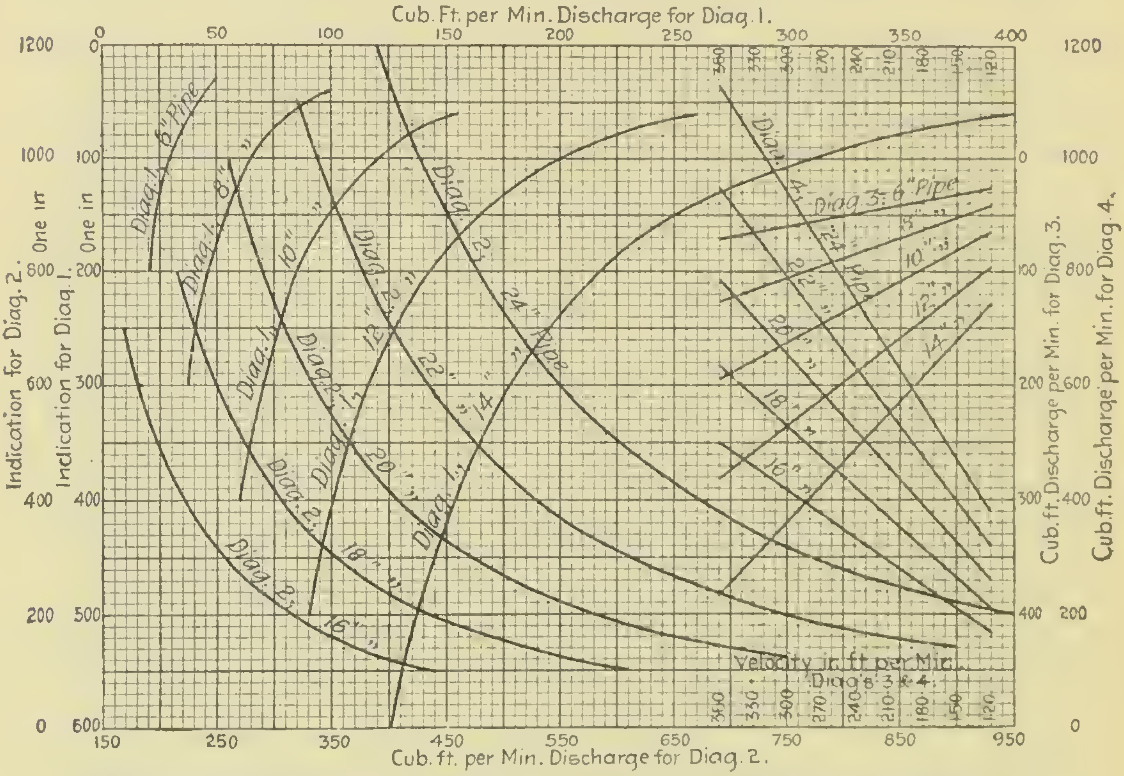


PLATE 1. DISCHARGE AND VELOCITY OF FLOW IN 6 TO 24 IN. PIPE SEWERS.

the inclination being taken on the right hand vertical scale, the discharge, in cubic feet per minute, may be found on the bottom horizontal scale. Diagram 2: the discharge, in cubic feet per minute, being taken on the left-hand vertical scale, the velocity, in feet per minute, may be found on the top horizontal scale. If it is desired to use the coefficient "N" = 0.015, then 18% should be deducted from the results obtained from the diagrams.

Plate 3. *Discharge and Velocity in Egg-shaped Sewers Flowing Full.*—There are two plottings on this plate: Diagram 1 for discharge, and Diagram 2 for velocity. They have also been computed from Kutter's formula, using "N" = 0.013. In Diagram 1 the inclination being taken on the right-hand vertical scale, the discharge in cubic feet per minute may be found on the bottom horizontal scale. In Diagram 2, the discharge, in cubic feet per minute, being taken on the left-hand vertical scale the velocity, in feet per minute, may be found on the top horizontal scale. If it is desired to use the coefficient "N" = 0.015, then 18% should be deducted from the results obtained by the diagrams.

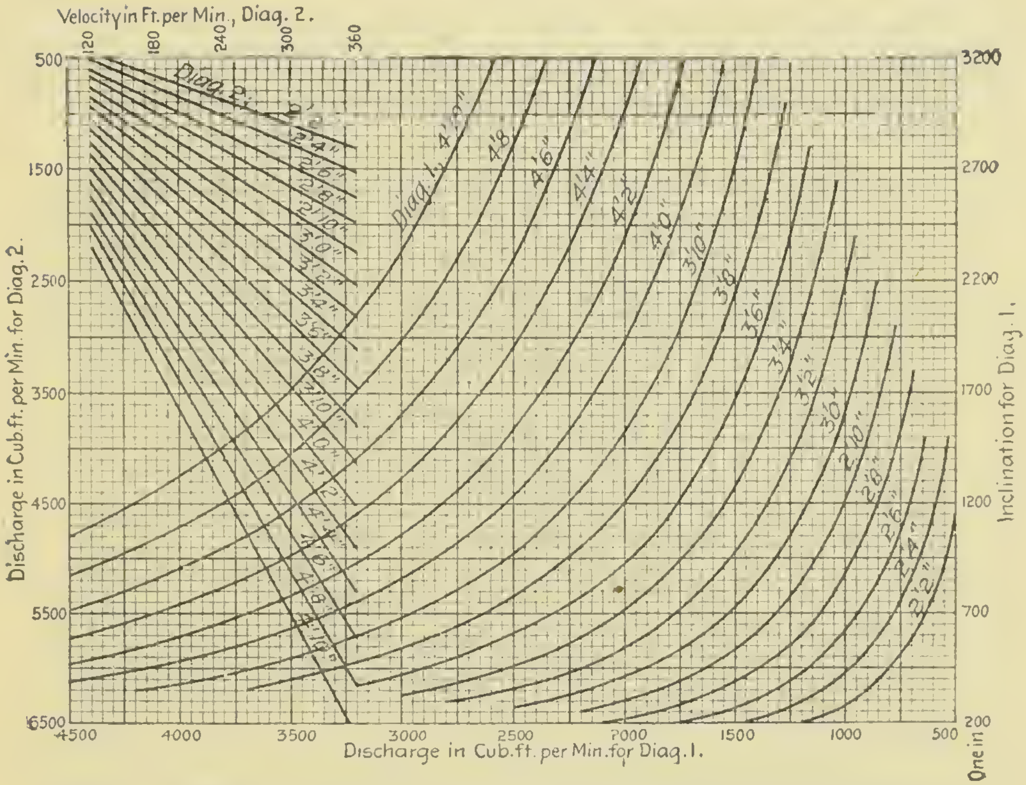


PLATE 2. DISCHARGE AND VELOCITY IN CIRCULAR SEWERS FLOWING FULL.

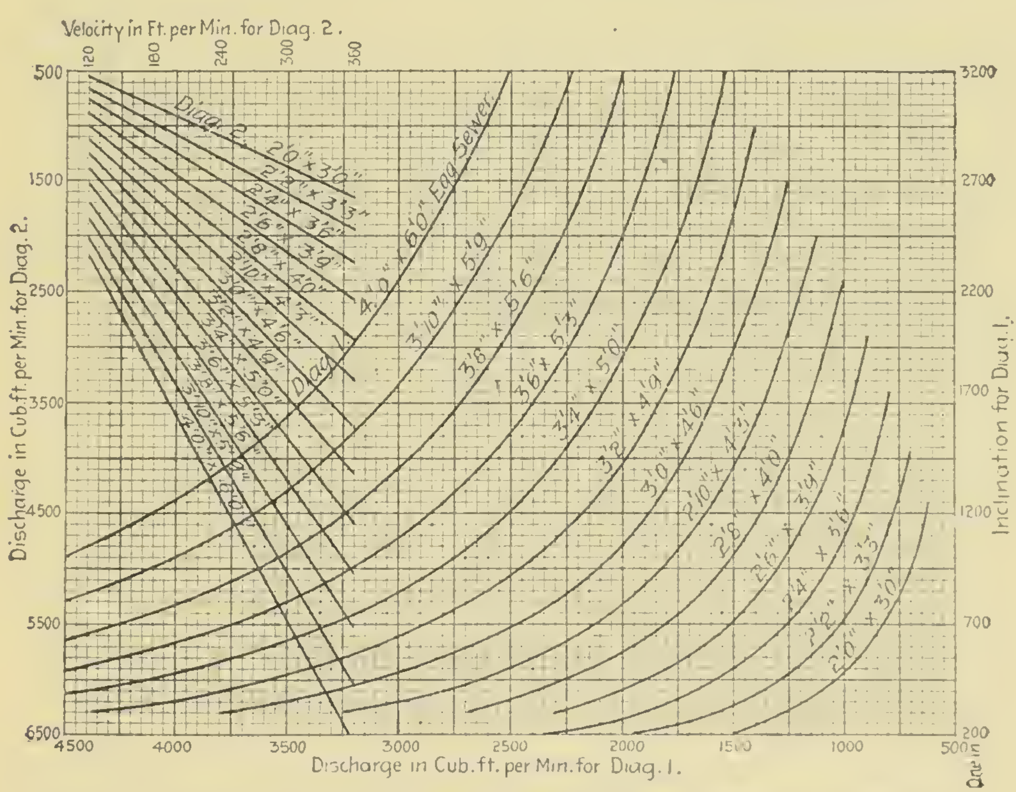


PLATE 3. DISCHARGE AND VELOCITY IN EGG-SHAPED SEWERS FLOWING FULL.

Plate 4. Ratios of Velocity and Volume of Sewers Partially Full to the Same When Full.—The full lines on this Diagram refer to circular sewers, and the dotted lines to egg-shaped sewers. The curves have been computed by Kutter's later formula, which allows for the decrease of the frictional coefficient as the mean radius

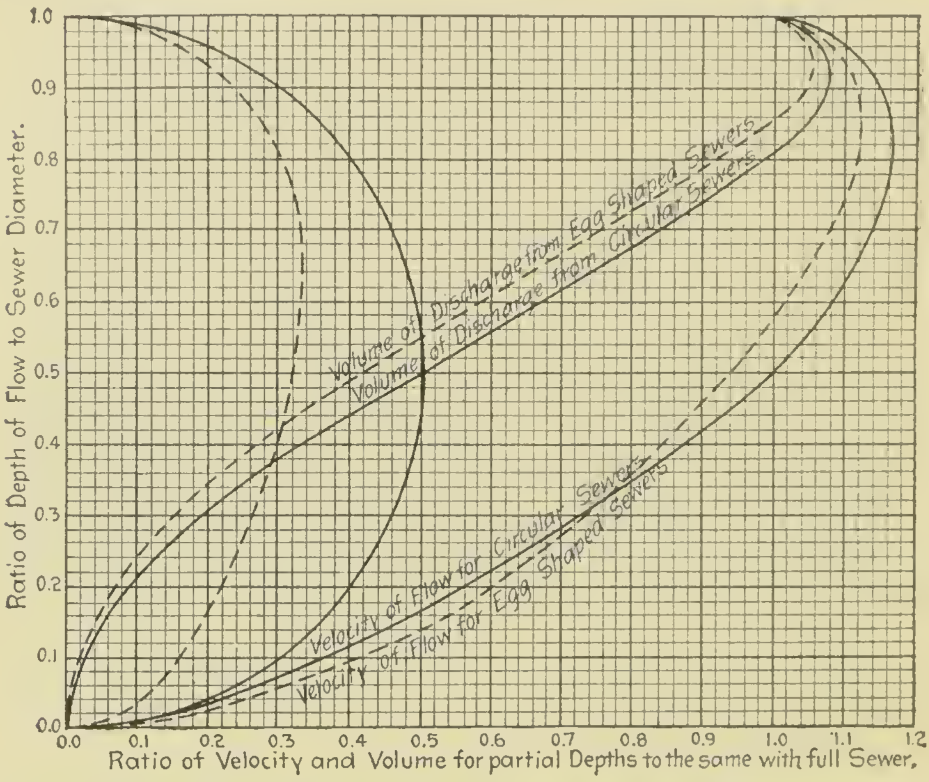


PLATE 4. RATIOS OF VELOCITY AND VOLUME OF SEWERS PARTIALLY FULL TO THE SAME WHEN FULL.

increases. The vertical diameter of the sewer and the volume of discharge and velocity of flow with the sewer running full are all taken as unity. If the ratio of the depth of flow to the sewer diameter be found on the vertical scale, then on the horizontal scale may be found the ratio of velocity and also of volume at that depth to the same when the sewer is flowing full.

APPENDIX TO REVISED EDITION.

SEWER GRADES.

PAGE 1, SECOND PARAGRAPH.—The proper grades of sewers and house connections given on pages 1 and 2 are subject to considerable modification in many places, owing to local conditions. For instance, in the main drainage system of London, the high level sewer on the north side of the Thames, varying from 4 ft. to 9½ by 12 ft. in size, has a quite rapid fall, ranging from 1 in 71 to 1 in 376 at its upper end and from 1 in 1,320 to 1 in 1,056 at its lower end. One of the stormwater sewers of Duluth, illustrated in ENGINEERING NEWS of Oct. 25, 1890, has a fall of from 7½ to 12½ per cent. This sewer is from 40 to 48 ins. in width, with an invert of granite blocks laid in Portland cement mortar, and was reported by HERING and ROSEWATER to be an excellently planned and executed piece of work. The same engineers recommended that the minimum fall of house drains be restricted to 1 in 48 in that city, while the plumbing and drainage regulations of Brooklyn, N. Y., require a fall of at least one-half inch to the foot. As regards drains, it may be assumed that a 4-in. pipe laid at a grade of 1 in 24 will safely carry off the wastes and rain water of about 2,000 sq. ft. of roof area.

SEWAGE PUMPS.

In the second paragraph on page 5, the subject of pumps for use during high water in the river or other recipient of the sewage, when the outfall sewer would be choked, is briefly noticed. An interesting installation for such a purpose was recently made at Winona, Minn., by URBAN H. BROUGHTON, Assoc. M. Inst. C. E. This city is situated on the right bank of the Mississippi River and has a population of about 18,500. During 6 or 8 months of the year the sewage flows readily from the outfall sewer, but during the remaining months, the river rises and the discharge is checked. Instead of putting in steam or gas pumps for use at such seasons, Mr. BROUGHTON used two Shone ejectors, illustrated on page 104, operated by an air compressor in the pumphouse of the water-works department, which is located about 1,000 ft. from the ejector station. About 4½ miles of sewers, principally 8-in., were laid to drain an area of 220 acres. In this manner the expense of an independent pumping plant and the necessary attendance was much reduced.

Consumption of Water in America.

The remarks on the consumption of water in American cities, given on page 9, require a little explanation. From the "Manual of American Water-Works," it appears that the consumption in a number of American cities is as follows: Allegheny, 238 gallons per capita; Baltimore, 94; Boston, 80; Buffalo, 186; Cambridge, 64; Camden, 131; Chicago, 140; Cincinnati, 112; Cleveland, 103; Columbus, 78; Dayton, 47; Detroit, 161; Fall River, 29; Indianapolis, 71; Jersey City, 97; Kansas City, 71; Lowell, 66; Louisville, 74; Memphis, 124; Milwaukee, 110; Minneapolis, 75; Newark, 76; New Orleans, 37; Omaha, 94; Paterson, 128; Philadelphia, 132; Pittsburg—company, 153; public, 144; Providence, 48; Reading, 75; Richmond, 167; Rochester, 66; St. Paul, 60; St. Louis, 72; San Francisco, 61; Syracuse, 68; Toledo, 72; Trenton, 62; Troy, 125; Washington, 158; Wilmington, 113; Worcester, 59. With such a wide variation as this, the necessity for carefully investigating the consumption of each city is self-evident. Some of the cities are reducing their per capita consumption. Detroit, for example, introduced meters in 1888 and 1889, and has decreased its total pumpage although over 7,000 additional families have been supplied from the mains.

Rainfall.

The table at the bottom of page 16 is condensed from an interesting essay on the relation between the density of population and the amount of impervious surface in cities, appended to a report made in 1889 by Mr. EMIL KUICHLING on a proposed trunk sewer for Rochester, N. Y. Engineers interested in the subject are referred to the paper, which is too long to reproduce here. The conclusions are that with a population of 25 per acre, 25 per cent. of the ground may be assumed as impervious and the discharge from the remaining 75 per cent. neglected; with 32 persons per acre, 33 per cent.; with 40 persons, 43 per cent.; and with 50 persons, 53 per cent. These results were obtained by measuring the discharge from different classes of surface, such as roofs, pavements, roads and highways, and then determining the amount of each class of surface with the different densities of population. Finally the equivalent in impervious surface of each of these classes was computed and the results added. A rather common rule in the New England States is to assume the maximum rainfall as 1 in. per hour and design the sewers to carry off the rain falling on one-seventh of the area under consideration, without taking into account the considerations elaborated in paragraph c, page 15, and shown graphically on page 17.

Run-Off.

Several inquiries having been made as to the original treatment by Prof. Baumeister of the subject of run-off, which was given in a considerably condensed form in the first edition of this book, the following translation is printed here. The condensed statement is retained in the body of the book, however, as it is sufficiently clear for the purposes of the engineer; it will be found on pages 17 et seq.:

"Buerkli has worked backward from an empirical formula employed by English engineers for determining the size of sewers and finds the following relation between the rainfall, R, and the volume of run-off, A:

$$A/R = 0.5 \sqrt[4]{G/F}.$$

Here F is the drainage area in hectares, G is the grade of the sewer per mille, and 0.5 corresponds provisionally to the coefficient x [see page 16]. This expression is open to the objection that the grade of the sewer has nothing to do with the occurrences outside it, and the grade of the drainage area corresponds more with the proper value of G. In American formulas, assuming G to designate the average inclination of the drainage area, the following forms occur as the value of the relation:

$$A/R = \sqrt[5]{G/F} \text{ and } A/R = \sqrt{G}/\sqrt{F}.$$

These appear to have been deduced experimentally in order to give "practical" widths to the sewers. From the point of view taken as a basis of the BUERKLI formula, the relation between the rainfall and the run-off, that is to say the relation between the retardation of flow from tracts of different areas, is

$$y = A/R = 1/\sqrt[4]{F}.$$

"In order to investigate the matter theoretically, we start with the interval of time which it will take a material point to run down a straight line of length l inclined at an angle of a degrees. Leaving out of consideration the influence of friction and denoting the acceleration of gravity by g, this interval of time is

$$\sqrt{2\,l \div g \sin a}.$$

If now under l is understood the length which a raindrop must pass in moving from the limit of the drainage area to the sewer, it is evident that the time which it will take to reach the sewer from the limit of a drainage area of any size is proportional to the square root of l. By the geometrical properties of similar figures, this length l is proportional to the square root of the drainage area, F. Hence the retardation is really inversely proportional to the fourth root of the drainage area. This corresponds fairly well with most of the observations, although for the cloudburst noted in the table on page 13 as occurring at Budapest the form

$$y = 1/\sqrt[6]{F}.$$

is more accurate. This ratio was adopted by BRIX in the preparation of plans for the sewerage of Wiesbaden, where the drainage area, like that on the left bank of the Danube at Budapest, has a heavy grade. For areas of less extent than 1 ha. the value of y should always be 1.

"From the heavy rainfall at Dresden, noted in the table on page 13, MANK has deduced an empirical value of y. Since the run-off from an area of infinitely small extent will equal the rainfall, he assumed that for F equal to O, y equals 1. It was found by direct measurement that for an area of 80 ha. y equaled 0.22. These two values were plotted and the assumption was made that the run-off from areas of more than 80 hectares would be governed by the same coefficient, y, as that from an area of 80 ha. A flexible rule was then made to pass through the two plotted points and be tangent to the straight line passing through the coefficient for 80 ha. on the diagram. The curve thus drawn is manifestly an arbitrary settlement of the problem, of questionable value. This is clearly shown in Fig. 2, where the curve is plotted with others. The ordinates stand for the values of y.

"The curve of BUERKLI certainly is most to be trusted. It was used recently in Mannheim, while in Chemnitz and Freiburg the MANK curve is used. It will be readily seen from Fig. 2 that there is an error made when it is assumed that the same coefficient of retardation may be used for every district of a city. A distinction should at least be drawn between sewers for small areas and large trunk sewers. Evidently in the case of the latter the most accurate course is to compute the flow and time of flow in the branch sewers, and then add them in proper order. Such a process is, however, tedious and inaccurate for branch sewers.

"From observations in Rochester, KUICHLING has proposed to regard the coefficient y not as dependent on the area F, but as a function of the duration of the rain, t; he places y equal to at, where a is a constant. This formula is said to apply to all cases where the time of the rainfall is shorter than the time it requires for the ground to become saturated and the rain to reach the sewer from all parts of the

drainage area. For rains lasting not more than one hour, it has been found that in Rochester R equals $[b-ct]$, where b and c are constants. Hence in this case

$$A = x\,y\,R\,F = x\,F\,a\,t\,(b - c\,t).$$

This expression reaches its maximum value for t equal to $[b - 2c]$. From the observations in Rochester of all rains lasting less than one hour, the constants are such that a rainfall lasting 51 minutes gives the greatest run-off and is therefore the most important in sewerage calculations.

"Experiments are still wanting which will show what is the influence of the slope of the drainage area on the quantity of storm water reaching the sewers. It may be taken into account by a suitable selection of the rate of rainfall and by a reduction of the amount of run-off from level ground. The rates of precipitation selected by BUERKLI show that the maximum run-off from steep ground may be twice that from flat areas. Moreover, it depends in a high degree upon the general form of the drainage area and on the direction of the streets."

CLAY AND CEMENT PIPE.

PAGE 29, SECOND PARAGRAPH.—The remarks of Prof. Baumeister concerning clay and cement pipes require some comment. Their use is so extensive in this country that the following table of sizes and weights, furnished by BLACKMER & POST, will be more in accordance with American practice:

STANDARD SEWER PIPE.

Diameter, ins.	3	5	8	10	12	15	18	24	30
Weight per ft., lbs.	7	12	24	33	42	58	80	125	220

DOUBLE STRENGTH CULVERT PIPE.

Diameter, ins.	12	15	18	20	22	24	26	28	30
Depth of socket, ins.	3	3	3	3⅛	3⅜	4	4⅛	4⅜	5
Thickness, ins.	1⅛	1¼	1½	1¾	1 5/6	2	2 1/6	2⅛	2½
Weight per ft., lbs.	48½	68	100	125	148	180	210	250	300

This pipe is all made in sections 2½ ft. long, and this length, as well as the depths of the sockets, was only adopted after a number of engineers had advised these dimensions rather than the smaller ones formerly in use. The thickness of the standard sewer pipe is uniformly about one-sixteenth the diameter. See ENGINEERING NEWS for Feb. 6, 1892.

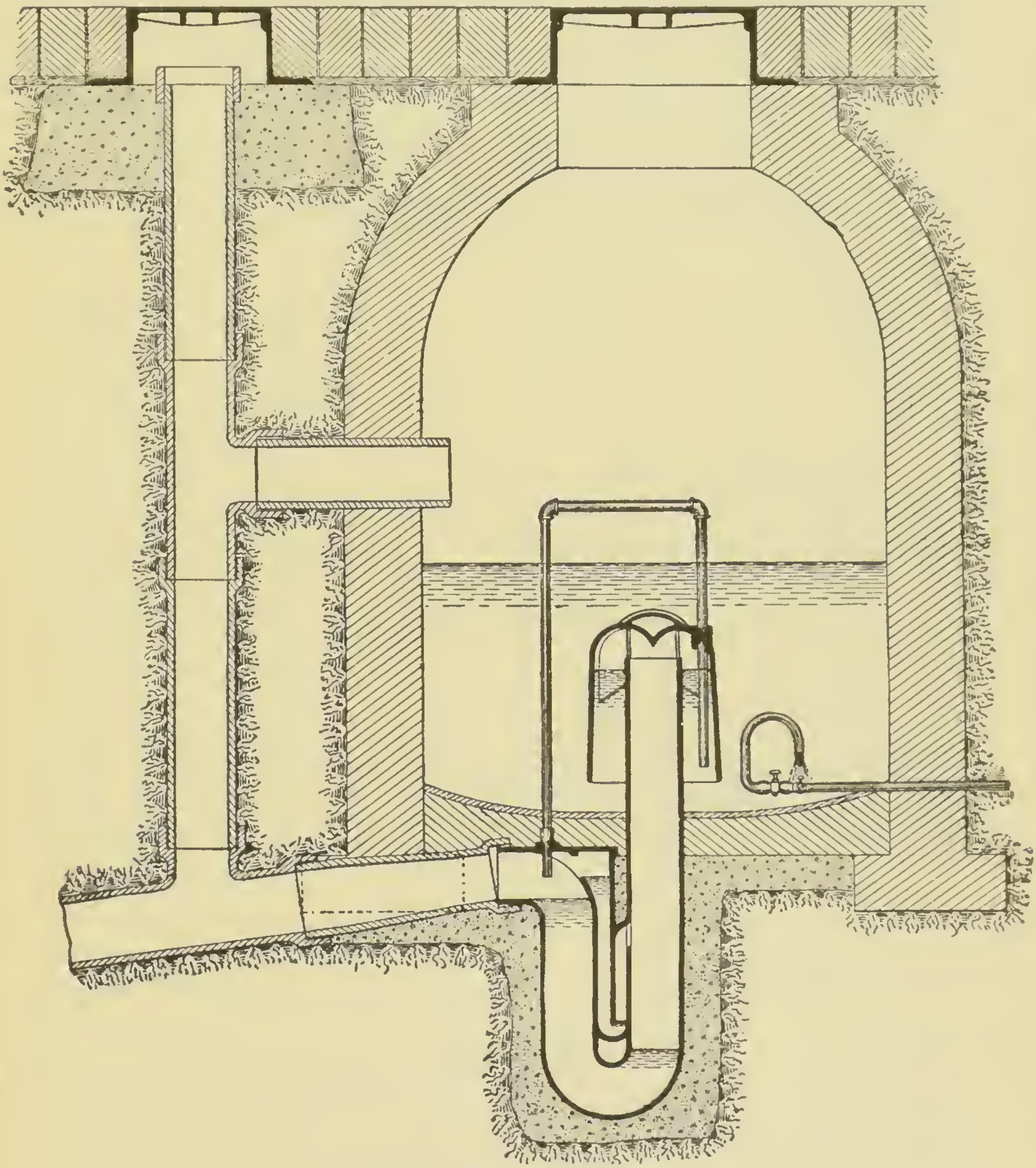
SIZE OF SEWERS.

PAGE 40.—A series of valuable diagrams for use in determining the proper size of sewers will be found in a paper by RUDOLPH HERING in Vol. 8 of the Transactions of the American Society of Civil Engineers, while a voluminous collection of tables is given in P. J. FLYNN'S volume entitled "Flow of Water in Irrigation Canals, Ditches, Flumes, Pipes, Sewers, Conduits, etc." Both diagrams and tables are based on KÜTTER'S formula.

FLUSH TANKS.

PAGE 77.—The use of flush tanks is becoming so general in the United States that the descriptions of PROFESSOR BAUMEISTER require supplementing. The RHOADS-WILLIAMS siphon, designed by the late WILLIAM G. RHOADS, of Philadelphia, and BENEZETTE WILLIAMS, of Chicago, jointly, consists of an annular intaking limb and a discharging limb terminating in a deep trap below the level of the sewer. As will be seen from the cut, below the permanent water line in the discharging limb, is connected one end of a small blow-off, or relief trap, having a less depth of seal than the main trap, the other end of which joins the main trap on the opposite side, at its entrance to the sewer and above the water line of

the trap. At the same point is connected an upright vent pipe which rises through the tank to a point above the high water line, and is turned down through the top of and into the intaking limb of the siphon, terminating at a given point above its bottom. As the tank fills (the main and blow-off traps being full) the water rises in the intaking limb even with



RHOADS-WILLIAMS SIPHON.

the level of the water in the tank, until reaching the end of the vent pipe, a volume of air is confined in the two limbs of the siphon between the water in the intaking limb and the water in the main trap. As the water rises higher in the tank the confined volume of air is compressed

and the water is depressed in the main and in the blow-off trap. This goes on until the water in the tank reaches its highest level above the top of the intaking limb, at which time the water is depressed in the blow-off trap to the lowest point and the confined air breaks through the seal carrying the water with it out of the trap and releasing the compressed air. In this manner the siphon is put in action, which continues until the water in the tank reaches the level of the intaking limb, and air is admitted through the vent pipe.

The walls of the tanks should be at least 8 ins thick, and the surrounding earth and concrete thoroughly consolidated about the parts of the siphon. The discharging end of the siphon should be set at least one-half the diameter of the sewer higher than the grade of the sewer. The siphons can be made of any desired size, but the following are most usually employed:

Sewer.—				
Diameter of, ins.	Discharging limb.	Discharge, cubic feet.	Diameter of tank, feet.	Capacity of 100 ft. of sewer, cubic feet.
6	5	27	4	20
8	6	40	4½	35
10	8	59	5	55
12	10	85	6	79
15	12	128	7	122

The ROGERS FIELD siphon illustrated by PROF. BAUMEISTER has been materially changed by COL. GEORGE E. WARING, Jr., and its form, as now extensively used, is shown in the accompanying cut. The discharging limb terminates in a weir chamber, which, when full to its overflow point, just seals the limb. Over the crest of the weir is a small siphon whose function is to draw the water from the weir chamber and thus unseal the main siphon, performing the same work as the vent pipe in the RHOADS-WILLIAMS type.

The siphon designed by ANDREW ROSEWATER and described in ENGINEERING NEWS of July 17, 1886, is also in extensive use. The VAN VRANKEN tank, described by PROF. BAUMEISTER, has been employed quite widely by STALEY and PIERSON in the separate sewerage systems designed by them.

HOUSE PLUMBING.

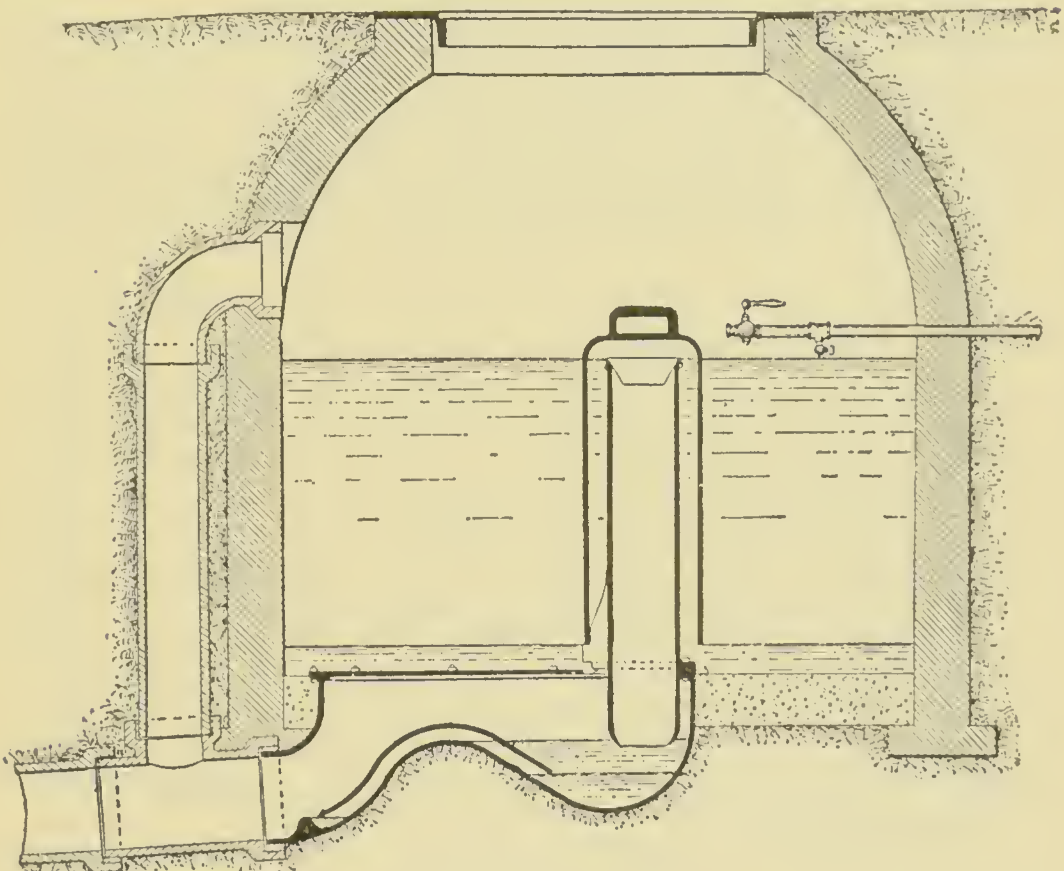
PAGE 80.—The portions of Chapter X referring to house plumbing by no means accord with standard American and English practice, concerning which HELLYER'S "Lectures on the Science and Art of Sanitary Plumbing" may be safely consulted.

VENTILATION.

PAGE 80, LAST PARAGRAPH.—Recent investigations apparently indicate that the direction of the wind at the openings of a sewerage system has a greater influence on the circulation of the sewer air than would be inferred from PROF. BAUMEISTER'S words.

PAGE 89.—A ventilating device known as the "Keeling Sewer Gas Exhauster and Destructor" was introduced in England in 1886, and has since been used in several places in that country. It will be made clear from the following description written by City Engineer H. PERCY

BOULNOIS, of Liverpool: "The apparatus consists of a hollow column surmounted by an ordinary street gas lantern, the column being perforated with slots just below the lantern. The base of this column is connected with the sewer by ordinary 6-in. drain pipe. The destructor is placed in the base of the column, and consists of an atmospheric gas burner. The gas is admitted from below, and just at the point where the gas pipe joins the jet of the burner is inserted an ordinary No. 6 Bray's gas jet. This is not lighted, but it acts as a regulator, as not more than 6 ft. per hour will pass through and be consumed under ordinary pressures. Above the atmospheric burner is an inverted fluted cone of cast-iron,



ROGERS FIELD SIPHON.

which becomes intensely heated when the gas is lighted. This cone is encased in an iron cover to prevent the loss of heat. Above this are other cones and fluted passages, all of which present a large area of heated surface. The sewer gas enters from below and passes up through and around the burner; while some of it is immediately burned, the whole of the remainder must come into contact with the hot iron cones, and before it passes away into the upper part of the shaft is deprived of all vital particle, injurious to health." The cost of gas for this device is stated to be from $25 to $30 a year, and this fact, coupled with the generally innocuous character of air in well designed and built sewerage systems (see

page 80), leads the editor to doubt the value of the apparatus except in certain special places; for example, over the underground public conveniences in use in many European cities.

With regard to the ventilating fans mentioned on page 89, they were tried in Liverpool, proved a failure and are now discarded. For further information on this point see the article in ENGINEERING NEWS of Oct. 25, 1890, on the sewerage of Liverpool.

POLLUTION AND SELF-PURIFICATION OF RIVERS.

PAGE 113. NOTE TO SECOND PARAGRAPH.—The pollution and self-purification of rivers are debatable questions and will probably remain undecided for many years to come. One important fact, however, must not be lost sight of in these discussions, viz.: it is the amount of impurities in the sewage of a town, rather than its total volume, which should be made the basis of calculations. This view of the matter, prominently advocated by RUDOLPH HERING and recently recommended by PROF. BAUMEISTER, makes the population the starting point in investigating the pollution of a river, instead of the more usual assumptions based on the total quantity of sewage.

CHEMICAL PRECIPITATION.

NOTE TO LAST PARAGRAPH, PAGE 125.—Too much importance cannot be attached to the proper adjustment of chemicals to sewage. This is plainly shown at the precipitation works at Worcester, Mass., fully described in ENGINEERING NEWS of Nov. 15, 1890. Here the sewage is extremely acid owing to the waste sulphuric and hydrochloric acids from large wire works discharged into it. This acid appears at the precipitation station once every six hours, and in sufficient quantity to render the sulphate of alumina, at first used, unnecessary. When the flow of acid is detected, a sufficient quantity of lime is added to the sewage to make it alkaline and it is then run into two of the precipitating basins, through which all the crude sewage during the remainder of the period of six hours is forced to flow. This process has resulted in a large saving of lime and alumina and has been found to give a better effluent than when the chemicals were added at regular intervals, in unvarying amounts.

Two methods of treatment have recently been brought into prominence in England since PROFESSOR BAUMEISTER published his work. In one of these the sewage is mixed with a precipitant called ferozone, composed of 24.64 parts of ferrous sulphate, 2.19 parts of aluminum sulphate, 3.3 parts of calcium sulphate, 5.17 parts of magnesium sulphate, 11.35 parts of silica, 19.01 parts of magnetic oxide of iron and 32.34 parts of water. The sewage thus treated is then filtered through a mixture of sand and polarite, the latter consisting of 53.85 parts of magnetic oxide of iron, 5.68 parts of alumina, 7.55 parts of magnesia, 25.5 parts of silica, 2.01 parts of lime and 5.41 parts of water. At Acton this process has given great satisfaction and several other places have since adopted it.

The other process is the invention of HERR WOLLHEIM, and is known as the Amines process. The precipitant employed is a mixture of from

30 to 50 grains of lime and 3 grains of herring brine to each Imperial gallon of sewage. The process is especially intended to produce a completely sterilized effluent and is said to be very rapid and complete. It has been used at Wimbledon for some time.

The WEBSTER electric process, which has been in use at Crossness for some time, cannot yet be said to have proved commercially successful: at least it is impossible to obtain authoritative statements of the cost of complete purification by this means, and until this is known it is unfair to draw any definite conclusions. Full particulars of the process will be found in ENGINEERING NEWS of April 13, 1889.

BERLIN SEWAGE FARMS.

PAGE 163, 14 LINES FROM BOTTOM.—By overflowed areas are meant the beds treated by intermittent filtration. In 1889-90 there were 5 334 acres at Berlin so operated, against 2,080 acres treated by broad irrigation. The total amount of ammonia abstracted by broad irrigation, which is only employed on grass plots, averages 98.87 per cent. during the year, while that abstracted from the sewage by filtration averages 97.82 per cent., or about one per cent. less.

PAGE 163, 2 LINES FROM BOTTOM.—The receiving basins of Berlin have an area of 410 acres and vary in size from 5 to 22 acres. They are formed by embankments about 3 ft. high and 13 to 20 ft. wide on top.

TOP OF PAGE 167.—The great extent of the Berlin sewage farms and the favorable character of their soil make the operating expenses comparatively small when contrasted with some other places. In 1889-90 there were four farms with a total area of 11,016 acres, which received sewage, while several others were under preparation for such purposes. Of these 11,016 acres, 2,080 were used for broad irrigation, 5,334 for intermittent filtration; 410 for settling basins or reservoirs for sewage during the winter, and the remainder of the land was used for dwellings, roads and gardens with the usual methods of cultivation. The total income during the year was $340,770 and the total expenditures for maintenance and wages were $287,092. The average cost of the farms per acre has been $356 and the interest on this sum and the repayment of loans called for $241,386, which must be increased by $6,988 for loss in valuation. Hence the net loss was $194,686, or something over $16 per million gallons of sewage received.

INDEX.

INDEX OF PRINCIPAL ILLUSTRATIONS.

(Only the principal illustrations are indexed below; all others may be found by consulting the preceding index under the proper head.)

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